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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 85.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON CEREAL AND FORAGE INSECTS.

I. THE LESSER CLOVER-LEAF WEEVIL.
By F. M. WEBSTER, M. S., *In Charge of Cereal and Forage Insect Investigations.*

II. THE SLENDER SEED-CORN GROUND-BEETLE.
By W. J. PHILLIPS, *Agent and Expert.*

III. THE CLOVER-ROOT CURCULIO.
By V. L. WILDERMUTH, *Agent and Expert.*

IV. THE SORGHUM MIDGE.
By W. HARPER DEAN, *Agent and Expert.*

V. THE NEW MEXICO RANGE CATERPILLAR.
By C. N. AINSLIE, *Agent and Expert.*

VI. CONTRIBUTIONS TO A KNOWLEDGE OF THE CORN ROOT-APHIS.
By R. A. VICKERY, *Agent and Expert.*

VII. THE SMOKY CRANE-FLY.
By JAMES A. HYSLOP, *Agent and Expert.*

VIII. THE COWPEA CURCULIO.
By GEO. G. AINSLIE, *Entomological Assistant.*

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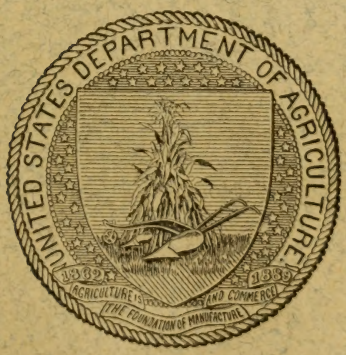

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1911.

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Cereal and Forage Insect Investigations.

F. M. Webster, *in charge.*

George I. Reeves, C. N. Ainslie, J. A. Hyslop, W. R. Walton, V. L. Wildermuth, R. A. Vickery, T. H. Parks, Herbert T. Osborn, W. Harper Dean,[a] T. D. Urbahns,[a] *agents and experts.*
W. J. Phillips, E. O. G. Kelly, Geo. G. Ainslie, Philip Luginbill, *entomological assistants.*
Nettie S. Klopfer, *preparator.*

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[a] Resigned.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., October 13, 1910.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 85, eight papers dealing with cereal and forage insects. These papers, which were issued separately during the years 1909 and 1910, are as follows: The Lesser Clover-leaf Weevil, by F. M. Webster; The Slender Seed-corn Ground-beetle, by W. J. Phillips; The Clover-root Curculio, by V. L. Wildermuth; The Sorghum Midge, by W. Harper Dean; The New Mexico Range Caterpillar, by C. N. Ainslie; Contributions to a Knowledge of the Corn Root-aphis, by R. A. Vickery; The Smoky Crane-fly, by James A. Hyslop; The Cowpea Curculio, by Geo. G. Ainslie.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

This publication includes a number of articles relative to insects attacking grain and forage crops. Although numbered consecutively, each paper is complete in itself, and, with a single exception, the species discussed have each been followed through their entire life cycle from egg to adult; the exception being Part VI, which is a contribution to a knowledge of the corn root-aphis, *Aphis maidiradicis*.

In Parts I to V and VII the species had not previously been carefully and exhaustively studied, and hence the information given is almost entirely new and original. In Part VIII, beside the inclusion of much new matter, previous errors are corrected and our knowledge of the cowpea curculio, *Chalcodermus æneus*, is practically completed.

While only two of the eight papers included in this bulletin relate to grain-affecting insects, this does not imply that greater stress is being placed on the investigation of forage insects. The two papers referred to happen to be pieces of work that were completed in time to include them in this publication. Of eight papers now reaching completion, which will be included in a similar publication in the near future, all but one relate to insects attacking growing grains.

F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

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[a] The eight papers constituting this bulletin were issued in separate form on November 18 and November 30, 1909; March 7, May 23, June 15, July 12, October 7, and September 21, 1910, respectively.

Part VIII, as originally issued, was erroneously paged as from *129* to *142*. The correct paging, given in this table of contents, is *133* to *146*.

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PAPERS ON CEREAL AND FORAGE INSECTS.

THE LESSER CLOVER-LEAF WEEVIL.

(*Phytonomus nigrirostris* Fab.)

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

The lesser clover-leaf weevil is one of the common, generally diffused insects of Europe, being found from Scandinavia southward into Egypt and Asia Minor, although the voluminous classical reports of Miss Ormerod give no intimation of its presence in the British Islands.

The technical literature of the species runs back into the latter part of the eighteenth century. Judging from accounts by the more recent European writers, its habits and development in the Old World do not differ materially from those as observed in America.

Mathieu [a] says: "It is common, and spread all over the fields and plains, especially on the trefoils."

Thomson [b] says that it is "not rare on high meadows all over Sweden."

Capiomont [c] informs us that "it is spread over the north and middle of Europe; also in Algeria, in Egypt, and Anatolie in Asia Minor. It lives on different species of Ononis, and especially on *Ononis spinosa*. The cocoon that the larva makes on the leaves of these plants is altogether similar in texture to that of *Hypera tessellata*, but it is a little smaller and more ovoid."

Kaltenbach [d] says with reference to this species that it "was found by F. Hoffman on *Buphthalmum salicifolium*, in the flower heads of which the larvæ live. The transformation takes place in a cocoon built from chaff leaves [p. 332].

"The larvæ live in the florets of the flowerhead of *Trifolium pratense*, wherein I have repeatedly taken the beetles [p. 124]."

Piero Bargagli [e] states that "in the vicinity of Florence it winters among the moss and under the bark of the alder in the perfect state;

[a] Annales de la Société Entomologique de Belge. Catalogue des Coleoptères de la Famille des Curculionidées de Belgique, p. 189, 1858.

[b] Skandinaviens Coleoptera, p. 173, 1865.

[c] Annales de la Société Entomologique de France, vol. 8, p. 227, 1868.

[d] Pflanzenfeinde aus der Klasse der Insekten, pp. 124, 332, 1874.

[e] Rassegna Biologica di Rincofori Europei, p. 95, 1883–84.

in this stage, and also as larvæ and pupæ, it probably lives on *Trifolium agrarium.* The individuals that have recently passed from the pupal to the perfect state are of a clear brown color and soon take on a green color with warmth [on drying].

"Larva and pupa.—It makes a little cocoon on the leaves of *Ononis spinosa* exactly similar in texture to that of *H. tessellata,* but smaller by half and perfectly ovoid."

HISTORY OF THE LESSER CLOVER-LEAF WEEVIL IN AMERICA.

Just when the species was introduced into America it is now impossible to state. Messrs. Hubbard and Schwarz collected it in eastern Massachusetts during the winter of 1873–74, and Mr. Blanchard, one of the oldest and most careful collectors of New England Coleoptera, is of the opinion that it might have occurred there as early at least as 1865. In connection with this information it must be remembered that up to the time of the publication by Le Conte and Horn of their "Rhynchophora of America North of Mexico," in 1876, our information on this group of insects was very obscure. Besides this, we do not know how long the species had been known by Provancher prior to his description of the species in 1877. As it first became injurious in New Brunswick and elsewhere in extreme eastern Canada, there are fairly good reasons for the assumption that it first gained a foothold in that part of the country, from which it spread by natural diffusion into New York and New England, and while Mr. Blanchard has cautioned me against placing too much stress on his opinion as above expressed, it seems to me that it is of sufficient value to be placed on record in this connection. As a matter of fact, the species in all probability occurred in limited numbers in the sections of the country above mentioned long before its discovery there by entomologists, precisely as was the case with the allied species *Phytonomus punctatus* in New York.

It was not, however, included in any of the earlier lists of the Coleoptera of America north of Mexico, appearing first in Austin's supplement published in 1880. Prior to this, however, in 1876, it had been included by Le Conte and Horn in their "Rhynchophora of America North of Mexico," its distribution being there given as "Massachusetts and Canada." A year later, Abbé Provancher described it in his "Petite Faune Entomologique du Canada" under the name *Erirhinus viridis.*

In 1884[a] Dr. James Fletcher stated that during the month of July he had found a small Phytonomus committing great damage in the clover at Dalhousie, New Brunswick. He had taken it for *P. nigrirostris* at first, but fancied it might be a different species, as nearly all the specimens reared were light cinnamon brown in color. (These

[a] See bibliography, p. 12.

specimens have since been identified as *Phytonomus nigrirostris*.) In the same year (1884) Mr. W. H. Harrington stated that *Phytonomus nigrirostris* occurred in considerable numbers in the vicinity of Ottawa, but that he had not found any evidences of the destructive habits described by Mr. Fletcher. He added, however, that it was known to attack clover in Europe.

In 1885 Dr. C. V. Riley stated that it had been observed by Dr. James Fletcher to attack clover in Canada. In 1899 Doctor Fletcher himself stated that in Canada it was a more general and destructive pest to clover than its congener, *P. punctatus*. In another place Doctor Fletcher stated that a considerable quantity of red and mammoth clover was injured about Ottawa by the insect just before the blooming season in June. During the same year Dr. C. H. Fernald stated that the smaller clover-leaf beetle, *P. nigrirostris*, was very common on the Massachusetts Agricultural College farm at Amherst, Mass., and quite destructive to the clover growing thereon.

In 1890 Doctor Fletcher stated that he had frequently found the larvæ feeding on the heads of clover, and that he had observed the insect in many parts of Canada.

In 1895 Mr. W. H. Harrington reported it as more numerous than any other of the 9 species of Curculionidæ hibernating in moss about the margins of swamps, November 17 to 23. Of the other 8 species there were, all told, 10 individuals and 35 of *P. nigrirostris*.

Mr. E. A. Schwarz (1908) states that *P. nigrirostris* is either a circumpolar species or else has been introduced into the Northern States long ago; for, as far back as the records go, it has always been quite common, ranging from New England westward to Michigan and Minnesota. Some years ago it had been found by him at Fortress Monroe, Va., and recently Messrs. I. J. Condit and J. H. Beattie, of the Bureau of Entomology, had found it at Arundel, Md., while others had found it near Washington, D. C., and on Plummers Island, in the Potomac River above Washington. Insects introduced into the Boreal Zone have not, in his opinion, the power of spreading southward, as can be exemplified by a large number of species. In this instance it seemed that there was another and distinct importation at some harbor south of New York.

Mr. C. O. Houghton (1908) gave the results obtained from a careful rearing of the insect in confinement, as well as some additional data relative to the time of appearance in spring. Although he labored under the disadvantage of rearing the insect under artificial conditions with clover leaves inclosed in vials and hence was unable to secure exact field results, yet his was the first published study of the development of the insect in this country. Further references to his paper will be made in the proper places.

Mr. R. L. Webster (1909) called attention to the seemingly maritime preferences of the beetle, noting its occurrence in New Bruns-

wick (Fletcher) and at Nantucket, Mass., where it was taken by the late Mr. Bolter, specimens being in the Bolter collection at the University of Illinois. The fact here brought out is that, although long ago found by Schwarz in Michigan and reported by him from Minnesota, it has never been abundant inland, and is still injurious only throughout the northern and central Atlantic coast region.[a]

TREND AND METHODS OF DISPERSION.

It seems probable that this species was introduced into either Canada or New England early in the last half of the last century. If, as is entirely possible, it gained its first foothold in America about Quebec or Montreal, Canada, it probably followed the same general trend of diffusion as other insects that were first introduced into that section, and spread southward into New England and New York, thence westward and either along the south shore of Lake Erie or across lower Ontario into the lower peninsula of Michigan, where Mr. Schwarz collected it about Detroit in 1875.

With reference to its diffusion southward there is considerable obscurity. As stated by Mr. Schwarz, page 3, insects introduced into the Boreal Zone do not spread southward in the same manner that they do to the westward, and in this the gentleman is in all probability correct. But the fact that this and other introduced species are being discovered along the coast as far south as the mouth of the Chesapeake Bay indicates that there may be some obscure force at work with which entomologists are not yet familiar. The fact that such species do not diffuse themselves over the country to the southward in a manner that can be followed as clearly as to the westward does not preclude the possibility of their occupying this southern country without separate and distinct introductions.

The current of the Gulf Stream, it is well known, is more or less parallel with, but at a greater or less distance from, the shore, and, while the direction is more or less northeasterly, there is a countercurrent that runs close inshore and in precisely the opposite direction. If one will stand upon the seashore and note the direction from which the débris comes that is thrown upon the beach he will notice that the trend is southward and that débris of this nature that is thrown on the beach at low tide is caught up as the tide comes in and is lodged still farther to the southward.

It does not seem impossible, therefore, that these insects may be carried into the sea by streams, or perhaps by winds blowing offshore at points along the New England and New Jersey coasts, carried

[a] According to some notes given me by Dr. F. H. Chittenden, the species was not found about Ithaca, N. Y., up to 1884, but was noted there in abundance in 1904. Also he had noted it abundantly about South Woodstock, Conn., in 1888, and along the seashore on Coney Island in 1891.

southward, drifted with the tide into the mouth of the Chesapeake Bay, and left with the driftwood and other rubbish where they can easily make their way to higher lands where their food plants occur in greater or less abundance.

No one has actually followed out this possible means of dispersion, but in accounting for the occurrence of transatlantic species which are known to have been introduced into either extreme eastern Canada or New England, and in a number of cases found about Norfolk and Fortress Monroe, it seems possible that some element of this nature is at work. It would be a profitable investigation for anyone who was conveniently situated to take measures to determine whether or not these introduced species may in this manner be carried southward and lodged along the coast.

INVESTIGATIONS CARRIED ON IN THE DISTRICT OF COLUMBIA AND VICINITY.

As has just been shown, the species has been known for some time both to the north and south of the District of Columbia, but only within a couple of years has it become at all common in the immediate vicinity of Washington. The information here given was obtained through the combined efforts of several field assistants, during brief temporary periods passed here in Washington, and well illustrates what may be accomplished by a free and hearty cooperation among individuals composing a limited body of investigators, even when working under very serious disadvantages.

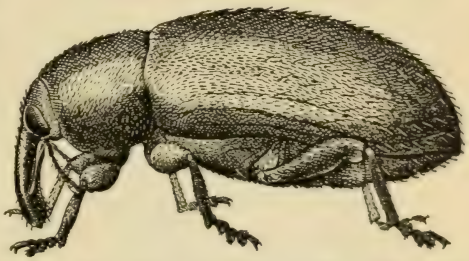

FIG. 1.—The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Adult, much enlarged. (Original.)

No credit whatever is to be accorded the author, beyond the direction of these investigations and a compilation of the results obtained.

The first note to be made on the species, here in the District of Columbia, was by Mr. Paul Hayhurst, who found, June 27, 1907, a single adult (fig. 1) on a leaf of red clover, *Trifolium pratense*, close by a freshly eaten hole in the leaf. The locality where it was found, Grant road, lies just north of the city and within the District.

Next, and nearly a year later, Mr. C. N. Ainslie, while awaiting a train connection at Weverton, about 50 miles northwest of Washington, in Maryland, found the blooming heads of clover infested as described below, but of course did not recognize the species until the adult was reared. The notes on this collection of larvæ are as follows:

"A handful of red clover heads infested with larvæ was gathered, May 20, 1908, beside the Baltimore and Ohio Railroad sta-

tion during a train wait. These larvæ (fig. 2) were eating in the bases of the florets, beneath the surface of the head (fig. 3, *b*), and moved rapidly out of sight when disturbed. About 25 per cent of the heads examined were infested. Observed but one larva in each head. Some twenty or twenty-five heads were brought to Washington to rear the larvæ.

FIG. 2.—The lesser clover-leaf weevil (*Phytonomus nigrirostris*): Larva, much enlarged. Natural length indicated by line under figure. Head and cervical shield, greatly enlarged, at left. (Original.)

"May 25. The larvæ have left the heads and spun coarse-meshed cocoons under the muslin that covers the jar in which they had been placed (fig. 4).

"On June 1 five adult beetles were found emerged from this material, and a sixth was nearly ready to leave the cocoon. The cocoons from which the five emerged have entirely disappeared."

On June 6 Mr. Ainslie, together with Mr. A. N. Caudell, found red clover heads, gathered from beside the electric-car line near Chevy Chase circle, north of Washington, at the District line, infested with larvæ and cocoons of *Phytonomus*. The beetle was quite common, perhaps 20 per cent of the heads being infested by larvæ. The

FIG. 3.—*a*, Clover head showing cocoon of the lesser clover-leaf weevil and leaf showing holes eaten by the larvæ; *b*, clover head attacked by the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and leaf eaten by the clover-leaf weevil (*P. punctatus*). (Original.)

cocoons (see fig. 4) were generally spun among the now nearly full-blooming heads (fig. 3, *a*), although one was found on a clover leaf by Mr. Caudell. One adult of a green color was taken, those that had previously been reared being brown with green lines on the thorax.

It now became necessary for Mr. Ainslie to leave for an indefinite period and Mr. Caudell took temporary charge of the investigation.

On June 12 he again visited the locality and made further search for this insect in heads of red clover, commencing first near Grant road, before mentioned, and working northward along the electric line toward Chevy Chase. Not a single clover head was found to be infested until the exact point where he and Mr. Ainslie had found the infested clover heads on June 6. The plants had been mown several days previous to Mr. Caudell's visit, but among a few heads that had escaped the mower at this particular point two were found to be infested. In the case of one, the adult had issued, and in the other it was still in the pupa (fig. 5), although it issued on the following morning. A further search was made to the westward, about the golf grounds, where occasional plants were growing, and four or five infested heads were found, but they were by no means as abundant as at the previously mentioned point near Chevy Chase circle. This would indicate a possibility of an excessive abundance in one particular locality, while occurring rarely or not at all elsewhere in the immediate vicinity.

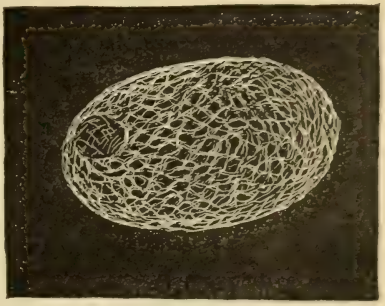

FIG. 4.—The lesser clover-leaf weevil: Cocoon. Much enlarged. (Original.)

From the material collected June 12 there appeared three adults on the 18th. These were found to be of a brown color, while those observed in the fields were all of a greenish hue.

On June 17 Mr. Caudell brought in from the fields a single larva and placed it in a breeding jar. On the 20th it spun a cocoon on the inside of the jar, pupated on the night of the 22d, transformed to the adult on the 25th, eating its cocoon, and finally emerged on the 26th, thus giving six days from the construction of the cocoon to the emerging of the adult. At this time Mr. Caudell was relieved by Mr. J. A. Hyslop, who watched the change of color in the adults from brown to green.

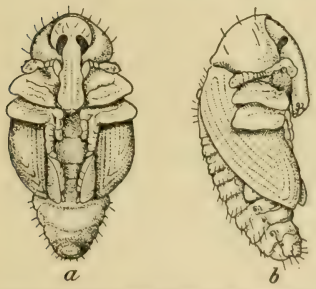

FIG. 5.—The lesser clover-leaf weevil. Pupa: *a*, Ventral view; *b*, lateral view. Enlarged. (Original.)

Of the three adults emerging on June 18, Mr. Hyslop found that on the 24th two had become of the normal greenish hue and the third was in a transitional state, the green appearing on the anterior half of the elytra. The individual that emerged on June 26 reached the full normal greenish color on July 7.

While all of this information is new to American literature, it will be noted that Hoffman long ago found the larvæ feeding in clover

heads in Europe. (See Kaltenbach, loc. cit.) There seems, however, to be a difference in the time required for the change in color, as between European and American adults, as Bargagli (loc. cit.) states that this change takes place "soon," on drying.

Invariably the adult devoured its cocoon or as much of it as could be detached from the object to which it was spun. In Mr. Houghton's excellent paper (1908) the change of color in the adult was not recorded and he was unable to account for the consumption of the cocoon by the single adult under his observation, except on the score of a total lack of other food.

We lost track of the adults in July, as Mr. Hyslop was absent from the District, so that no connected observations could be made, but it appears that after developing in the fields the beetles disperse very much as do those of *P. punctatus*, which, during summer, is as likely to be found crawling over the walks and pavements of cities and towns as anywhere else.

On September 23 the author took a single individual, either an undersized female or a male, on the inside of his office window, while Mr. Hyslop found a single individual at the roots of a wheat plant in the middle of a wheat field at Marion, Pa., November 21, 1908. This concluded the first year's observations on the species.

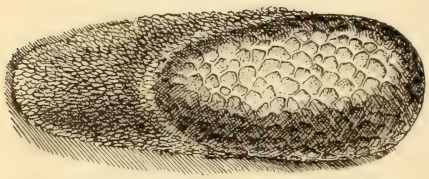

FIG. 6.—Egg of the lesser clover-leaf weevil placed interepidermally in leaf, with part of egg surface exposed, showing granulation. Highly magnified. (Original.)

Mr. Houghton states in his paper that the earliest date on which he found adults in spring in Delaware was April 12. Mr. Hyslop found adults in the same locality as that visited in 1908, among the dead and dried leaves and stems of the previous year's growth, on April 1, when the sexes were pairing preparatory to oviposition. Adults taken at this time, however, did not deposit eggs for a week, so it would seem that they were only just commencing their activity. He had not searched for them earlier, the season being somewhat backward, and it is probable that they may be found about the clover plants as soon as the weather becomes warm enough to start the growth of the young leaves. Female beetles confined in small vials with clover leaves deposit eggs somewhat as described by Mr. Houghton, as follows:

"Several were found situated interepidermally, sometimes singly, sometimes in pairs. They were inserted through punctures, sometimes made through the upper epidermis of the leaf, sometimes through the lower, apparently. * * * The unusual way in which part of the eggs were laid in this case was that a bunch of six, somewhat irregularly stuck together, was deposited upon one of the leaves."

Mr. Hyslop found that the female, when confined on a leaf, frequently placed her eggs interepidermally in the cavity between the upper and lower epidermis along the sides of the midrib, inserting them through an opening made on the upper surface of the leaf, and in groups of from one to four. About this time Mr. Hyslop was expecting daily to start for the Pacific coast, and both he and Mr. V. L. Wildermuth carried on the investigation for a short time together, but neither was able to find eggs deposited in or on the surface of the leaves, in the fields, although they did find them pushed transversely under the epidermis of the base of the leaf sheaths (see fig. 7). When the female was confined on a single leaf, eggs were often found in groups, placed with no reference to the midvein, and in such cases there was a deceptive resemblance to a matrix of adhesive mucilaginous matter with the eggs placed on instead of in the leaf. Mr. Wildermuth, however, discovered that this illusion was due to the fact that the incision in the leaf was made in the upper surface, through the substance to the lower epidermis, so that when the eggs were pushed into the sac thus formed they lay between the leaf-substance on one side and the epidermis on the other, and were thus forced against this elastic and nearly transparent lower epidermis, which, while remaining intact, became so adjusted about the group of eggs as to give them the appearance of having been placed on the surface and in a matrix which hardened and adhered to both eggs and leaf surface. Figure 6 shows an egg greatly enlarged, with the epidermal covering removed, showing the granulation of the eggshell. Mr. Wildermuth, late in April, examined hundreds of leaves without finding a single egg on the leaf itself, while there was no difficulty whatever experienced in finding them, more often in threes, placed under the epidermis of the basal leaf sheaths as shown in figure 7. So uniformly was this the case

FIG. 7.—*a*, Clover plant showing place of oviposition of the lesser clover-leaf weevil; *b*, section of same, greatly enlarged; *c*, leaf showing holes made by larvæ of the lesser clover-leaf weevil (*Phytonomus nigrirostris*) and edges eaten out by the clover-leaf weevil (*P. punctatus*). (Original.)

that there seemed no other alternative than to concede this to be the normal mode of oviposition. Eggs removed from the basal leaf sheaths are illustrated, greatly enlarged, in figure 8. While they are somewhat obscure when freshly deposited, they change to a dark color in a few days, and, though minute, are then easily distinguishable.

SEASONAL HISTORY.

In the vicinity of Washington, D. C., the adults come forth from their hibernation in the fields as soon as the warm weather starts the young growth of the clover, probably during the last of March in ordinary seasons. The sexes pair, and egg deposition soon commences. Females brought from the fields near Washington, on April 1, during the somewhat cold and backward spring of 1909, deposited eggs indoors on April 6. In the fields the first eggs were probably overlooked because it was not known on just what part of the plant it was necessary to search for them. As observed by Mr. Wildermuth, the egg period varied from seven days twenty hours to eight days twelve hours.

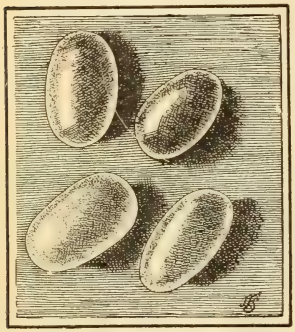

FIG. 8.—The lesser clover-leaf weevil: Eggs. Greatly enlarged. (Original.)

The larval period varies from seventeen to twenty days, the former being probably near the normal. The larva molts twice, the first instar occupying from three to seven days, the second from six to seven days, and the third about seven days.

The pupal stage occupies, normally, about six days, and the entire period from egg to adult about thirty-two days. Of course temperature will always affect the length of the different periods to some extent.

While there is clearly but a single annual generation, the breeding season is greatly prolonged, egg deposition probably covering upward of six weeks, and late in this season all stages may be observed at the same time.

While the larvæ can feed on all parts of the clover plant above ground, they prefer the tenderest unfolding leaves, and in the fields they select these parts and feed among the folds; later, they attack the heads, both young and in full bloom (fig. 3, *b*). While the larvæ of both *Phytonomus punctatus* and of the species under consideration frequently occur on the same plant, the work of the two is quite different and easily separated. This difference is shown in figures 3 and 7, the latter figure illustrating the work of both species in the same leaf.

After emerging, the adults probably scatter abroad over the fields and hibernate among leaves, matted grass, and other rubbish.

DESCRIPTIONS.

The adult (fig. 1).—"Green; snout black. Inhabits England. Herbst. Arch. tab. 24, fig. 3. Head brown; snout cylindrical, black, polished; thorax gibbous, rounded, green, with 2 dorsal brown lines; shells downy, immaculate; legs brown." (Original description.)

The egg (figs. 6, 8).—The egg is ovoid, pale greenish at first, but darker as incubation advances, surface distinctly reticulated. Length, 0.55^{mm} to 0.63^{mm}; width, 0.35^{mm} to 0.36 ^{mm}. (Description by Hyslop and Webster.)

The young larva.—The newly hatched larva is 1.25^{mm} in length and 0.25^{mm} broad. Color white, with pinkish tinge, best seen on ventral surface. Head large, with the cervical shield pale brown, the latter divided by a broad median white line, the inverted V-shaped mark on head also white; body with sparsely placed setæ, longer and more conspicuous on the anal segments. In a short time the pink tinge disappears, the head becomes black, and the inverted V-shape line extends across the now black thoracic shield, and along the entire length of the body it is produced in a very delicate, pale median dorsal line. (Description by Wildermuth and Webster.)

The full-grown larva.—The full-grown larva is of a greenish straw color. Head light brown. The inverted V-shaped white line is still quite visible on the head. The cervical shield has lost its color, but the faint dorsal white line is still noticeable throughout the whole length of the body. The setæ are still prominent, there being four long ones on each segment, those on the last two segments being very long. (Description by Wildermuth and Webster.)

The pupa.—Pupa distinctly resembling the adult. Abdomen almost colorless, with a slight tinge of yellow. Head, thorax, and appendages increasing in density of black from time of pupation until emergence. A very distinct white line passes through center of dorsal surface of thorax and head, and continues on through the beak, where it reaches its greatest width. (Description by Wildermuth.)

NATURAL ENEMIES.

Two parasites have been reared from the larvæ of this species. Among the material brought into the office by Mr. Caudell on June 12, collected about the golf grounds near Chevy Chase, were two cocoons of this species, one of them containing a larva which at the time appeared to be dead. A few days later, however, this larva made its way out of the cocoon, and in crawling toward the mouth of the breeding vial it pushed its way between the end of the cork stopper and the side of the vial, where it transformed to a puparium. On the morning of June 23 from this puparium a small fly emerged, determined by Mr. D. W. Coquillett as *Hypostena variabilis* Coq., one of the Tachinidæ. There can be no doubt that it is parasitic on the larva of *P. nigrirostris*.

A larva taken from a clover head beside Grant road, in the District of Columbia, June 26, 1908, developed into an adult hymenopterous parasite that emerged July 8, 1908. It was determined by Mr. J. C. Crawford as *Bracon* sp.

The pupæ are destroyed by a fungus [*Empusa* (*Entomophthora*) *sphærosperma*]. Should the pest ever become excessively abundant it will prove not only a difficult one to manage, but decidedly destruc-

tive as well. The effect of this fungus will, however, probably be sufficient to hold it in check, as it does its larger relative, *Phytonomus punctatus*.

FOOD PLANTS.

Dr. James Fletcher found this weevil attacking red clover (*Trifolium pratense*) and mammoth clover (*T. medium*) about Cttawa, Canada. Mr. Wildermuth observed the adults feeding on the leaves of alfalfa (*Medicago sativa*), crimson clover (*T. incarnatum*), white clover (*T. repens*), and alsike clover (*T. hybridum*) in the vicinity of Washington, D. C.

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PAPERS ON CEREAL AND FORAGE INSECTS.

THE SLENDER SEED-CORN GROUND-BEETLE.

(*Clivina impressifrons* Lec.)

By W. J. Phillips,
Agent and Expert.

INTRODUCTION.

Observations have been carried on for several years in the vicinity of New Paris, Ohio, on an interesting little beetle known as the "slender seed-corn ground-beetle" (*Clivina impressifrons* Lec.). As much new information has been secured regarding its early development, and since it is probably responsible for some of the injuries charged up to other insects, it has been thought advisable to make it the subject of a short paper. As it works below ground, in the kernels of corn, and confines itself to swampy, peaty soils, the farmer is likely to believe that the seed fails to germinate and to attribute the cause to excessive moisture, cool weather, and inferior seed, never dreaming that this modest little creature is busily collecting his toll, sometimes as many as fifteen or twenty individuals being found in or about a single hill.

The writer wishes to acknowledge his indebtedness to Prof. F. M. Webster, under whose direction this work was carried out. To the patient and untiring efforts of Mr. V. L. Wildermuth we owe the information herein presented concerning the habits of the larvæ and pupæ. The writer, having previously planned the work, carried on observations on the adults and their economic relations, and is responsible for the descriptive matter. Acknowledgments are due Mr. Frederick Knab for helpful suggestions in the preparation of descriptions.

DISTRIBUTION.

The slender seed-corn ground-beetle belongs to a very large genus, there being over two hundred species, distributed throughout the entire world, with the exception of the extreme northern and southern latitudes. The genus as a whole is supposed to be carnivorous. The species under discussion is a native of the eastern United States and is the only one on record as being a plant feeder. Doctor Le Conte described the species in 1884 and gave New York as its habitat. Since that time it has been found in Canada, New Jersey, Ohio, Indiana, Illinois, Iowa, and Kansas.

DESCRIPTIONS AND LIFE-HISTORY NOTES.

THE EGG (fig. 9, *a*).

A correct description of the egg can not be given, as all those observed are from dissections and have not retained their normal shape. They are a little over 1 millimeter in length and over one-half millimeter thick, obtusely rounded at ends. The chorion is minutely reticulate. In color they are a delicate white. It is probable that they are deposited somewhere below the surface of the soil, as the larvæ are blind and are found quite deep in the earth. Nothing is known relative to the period of incubation, as the eggs have never been found in the fields. Numbers of adult females were dissected and none contained more than three to four mature eggs, but they could be found by this method from early spring on throughout the entire summer.

THE LARVA (fig. 9, *b*, *e*, *f*).

Following is a detailed description of the larva:

Color: Head and prothoracic plates dark brown, plates of the other two thoracic segments much lighter; cerci and anal tube brown, somewhat dusky at the tips; abdominal segments pale yellowish; tips of mandibles black; legs dusky. Just after molting the larva is a delicate creamy white.

Form: Depressed fusiform; breadth greatest at about the fourth abdominal segment; length a little over six times the greatest breadth; thoracic segments narrower than the abdominal ones.

Head quadrate, depressed dorsally, with a deep, broad furrow starting at the base of the antennæ and extending in a posterior direction, gradually fading out; epistomal sutures joining near the base of the head; a deep impression on each side of the head, near the base, extending beneath and then anteriorly to base of mandibles; on the dorsal surface there is a chitinous ridge at the base of the antennæ.

Ocelli absent.

Epistoma reaching posteriorly about three-fourths of the distance from the front of the clypeus to the occipital foramen, its lateral sutures sinuate; frontal angles obtuse, rounded.

Clypeus fused with the epistoma. Labrum bilobate, with deeply serrated margin.

Setæ: Dorsally there is one large and one small seta immediately at the base of the mandibles; a large seta on each side near the margin of the epistomal area, posterior to the antennæ; several small setæ on the clypeal and epistomal areas; a large seta and several smaller ones near the center of the frontal angles; two large setæ and several small setæ on the lateral margin of the head; one large seta near the base and slightly ventral of the antenna; a small seta ventral of this last one; numerous medium-sized setæ on the ventral aspect.

Antennæ four-jointed; first two joints clavate-cylindrical, joint 2 four-fifths as long as joint 1 and at the base about three-fourths as thick; joint 3 broadly clavate and about one-third longer than joint 2, its outer angle truncate and bearing a prominent acorn-shaped appendix; joint 4 slender, cylindrical, and slightly pointed at the extremity; joint 3 with two large setæ toward the apex, one on the outer and one on the inner margin, and one on the dorsal face near the base; joint 4 with three large and two small setæ at the distal extremity.

Mandibles falcate, slender in front of the retinaculum, apparently smooth; retinaculum much nearer the base than the tip, small, directed slightly backward; a medium-sized seta on the outer margin of the mandible near the base.

Maxillæ: Maxillary stipes obconical, about 3.6 times longer than wide at its widest point, slightly curved; two large setæ on the outer and one on the inner margin near the distal extremity. Outer lobe probably slightly surpassing the first joint of the palpus; joint 1 clavate, with small seta on inner distal margin, about five-eighths as long and one-half as broad as joint 1 of the palpus; joint 2 slender, conical, and fully as long as joint 1. Inner lobe conical, short and inconspicuous, a large seta at its base. Palpigerous stipes about three-sevenths as long as joint 1 of the palpus, and larger; joint 1 slightly clavate, about three times as long as broad; joint 2 apparently cylindrical, not quite half as long as joint 1 and about one-half as broad; joint 3 conical, small, about two-thirds as long as joint 2.

Labium: Mentum almost quadrate, slightly convex, smooth, much narrower at the proximal than at the distal end, slightly longer than broad at its broadest point; just

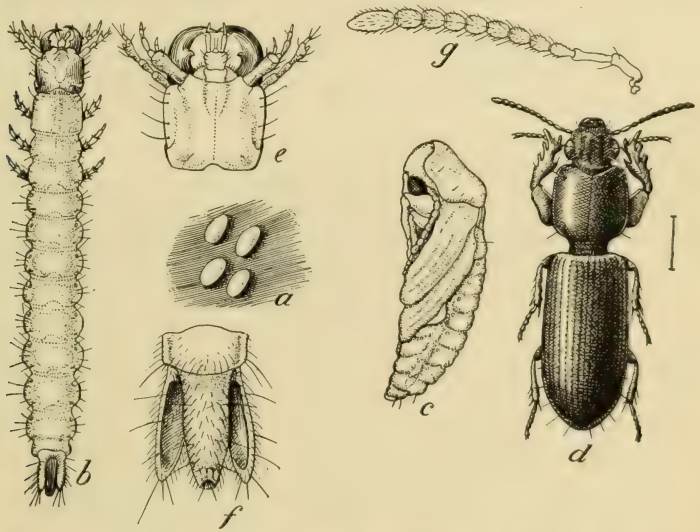

FIG. 9.—The slender seed-corn ground-beetle (*Clivina impressifrons*): *a*, Egg; *b*, larva; *c*, pupa; *d*, adult; *e*, ventral view of larval head; *f*, ventral view of anal segment; *g*, antenna. All much enlarged. (Original.)

below the insertion of the palpi is a large seta; quite hairy except on the ventral surface; ventral surface with a very slight groove down the center; on either side of the labium are three or four very large setæ, probably arising at its base; joint 1 of the palpus slightly constricted near the base, the distal end the largest, little longer and about the same width as joint 1 of maxillary palpus; joint 2 conical, and nearly as long as the two distal joints of the maxillary palpus; the stipes are slight elevations of the mentum, having no distinct outline. Ligula minute, nearly quadrate, nearly as long as joint 1 of the palpus and bearing two small setæ.

Thorax: Prothorax nearly as long as mesothorax and metathorax combined; plates much more strongly chitinized; a slight impression on each side near the anterior extremity; two large setæ on each lateral surface; one large seta on the lateral surface of the other two thoracic segments; a furrow down the center of each segment (on the dorsum); one pair of thoracic spiracles situated on the mesothorax just anterior to the insertion of the legs. Mesothorax and metathorax about equal in size.

Legs: Middle pair slightly the largest; coxa very stout, very thick at the base and tapering to about one-third the size at the distal extremity; numerous stout spines on

the anterior face and a few on the posterior; trochanter not quite three-fourths as long as coxa on its outer margin; inner margin about one-half as long as outer, distal extremity the largest; femur very slightly clavate, its longest side three-fourths as long as the coxa; distal extremity not quite as large as the distal extremity of the coxa; tibia two-thirds as long and two-thirds as large as femur, very slightly clavate; tarsus bearing one large claw. A whorl of spines at distal end of tibia; femur and half the length of trochanter with a double row of spines on ventral surface; one very long, slender spine on the trochanter, at apex on ventral surface.

Abdominal segments without chitinized plates, increasing in size (in full-grown larvæ) from base outward until reaching segment 4 and then gradually decreasing; a pair of spiracles on the anterior lateral aspect of each of the first 8 abdominal segments, so placed as to be visible from above; they are circular and much smaller than the thoracic spiracles; a large seta on the lateral aspect of each abdominal segment. The 9th segment bears the anal tube and the cerci.

Cerci slightly shorter than the longest abdominal segment, coriaceous, not motile; seen from above they are broad and slightly convex; beneath concave, tapering gradually toward their distal extremity; the two give the appearance of the letter "U"; the 8 large setæ symmetrically arranged with reference to the corresponding setæ on the other cercus; a row of small setæ on the inner margin of each cercus, the setæ arranged symmetrically with each other; the other portion of the cerci is densely covered with setæ.

Anal tube apparently as long as the cerci; from lateral aspect appearing cylindrical, apparently depressed dorsally, curving slightly downward at the tip; ventral margin of tip irregular in outline and slightly notched; from dorsal and ventral views the tube has the appearance of a truncated cone; ventrally there are numerous large setæ and a dense covering of small setæ; dorsal surface sparsely covered with setæ.

The larvæ are veritable little cannibals, for besides devouring the larvæ and pupæ of other insects they will, in confinement, destroy each other. They are very difficult to rear, and in no case could they be carried further than one or two molts. Hence, the length of the larval stage and the period between instars could not be ascertained. In confinement they feed readily upon small larvæ and the pupæ of other ground-beetles. It is almost impossible to make accurate field observations on them, as they are found at a depth of from a few inches to about 2 feet, depending upon the amount of moisture in the soil. Soon after a rain they will be found within a few inches of the surface, while during a dry period they go quite deep, apparently seeking moisture.

THE PUPA (fig. 9, *c*).

A detailed description of the pupa is given below:

From the lateral aspect: Oblong, increasing in thickness gradually toward the anterior extremity; prothorax depressed; antennæ directed dorsally, then ventrally, around the femora of the first two pairs of legs, the distal half resting between the elytra and the femora and tibiæ of the middle pair of legs. Front femora resting near the eye. Elytra and wings long and narrow and folded over the posterior pair of legs, the tarsi of which reach to the posterior margin of the sixth abdominal segment.

Ventral aspect: Head directed downward between the first two pairs of legs, not quite one-third length of entire pupa; mandibles closed but not overlapping; from the base of the mandibles to the tip about one-third as large as the portion of the head above them; labrum broad and short, and extending halfway down the mandibles;

maxillary palpi conical, long, parallel, and surpassing the mandibles by fully three-fourths their length; antennæ disappearing behind the fore and middle pairs of legs, coming into view again between the middle tibiæ and the elytra. Setæ showing but slightly until just before emergence of adult.

Legs: Fore and middle legs directed forward so that the maxillary palpi touch the anterior face of the anterior tibiæ near the distal extremity; anterior faces of the large, terminal, tibial spurs nearly touching; tarsi touching for almost the entire length, and lying between and above the tarsi of the middle legs, extending posteriorly. Middle tibiæ just posterior to front tibiæ, parallel to and very close to them. Claws divergent. Middle tarsi partly beneath the wings, their ventral surfaces facing. Hind tarsi extending beyond the wings and converging at the posterior margin of the sixth abdominal segment; ventral surfaces facing; claws divergent.

Elytra and wings completely covering the hind legs, with the exception of the tarsi, and almost touching beneath. No setæ on the ventral surface of the abdomen.

The pupal stage lasts from nine to ten days. When found in the fields the pupa is always inclosed in a little, oblong, earthen cell, about one-third of an inch long. Immediately after pupating it is a delicate creamy-white color. The eyes gradually turn darker, first becoming red and then black. Other parts of the body change to a darker yellow and then to a brownish color. The pupa is inclosed in a delicate, transparent, membranous covering, which splits down the dorsum when the adult emerges. Pupæ are found at a depth of from a few inches to about 2 feet, depending, apparently, on the amount of moisture in the soil at the time of pupation.

THE ADULT.

The adult (fig. 9, *d*, *g;* fig. 10) is of a dark, shiny-red color and is somewhat flattened and elongate. The wing covers are narrower than the thorax. The hinder part of the body articulates with the prothorax by means of a short peduncle. The fore legs are very broad and somewhat flattened, the tibiæ bearing several large teeth. The original description by Le Conte will probably not be out of place here:

Length 3¼ lines; breadth ⅔ line; dark rufous; front with three wide and deep longitudinal impressions, the middle ones abbreviated at the ends so as to form an oblong fovea; thorax oblong, rounded behind, but little convex, with longitudinal line deeply impressed; elytra narrower than the thorax, parallel, striate; striæ punctate, third interval with impressed points.

When it first issues from the pupal case the adult, or beetle, is pale yellow in color, gradually turning to the characteristic shiny red.

NUMBER OF GENERATIONS.

It seems that there are no well-defined broods or number of generations. The species breeds throughout the entire season, very small larvæ up to full-grown pupæ and adults being found at any time during the summer. The sexes were found in copula, June 14, 1909.

HIBERNATION.

The insects pass the winter in the adult stage. In November, 1908, careful search was made, during several days, in the cornfields for larvæ and pupæ, but none could be found, though there were plenty of adults present. This is not proof but a good indication that they pass the winter only as adults. Nothing, of course, is known of the eggs as they occur in the fields.

CHARACTER OF GROUND MOST LIABLE TO INFESTATION.

Larvæ, pupæ, and adults seem to confine themselves to low, swampy, peaty soils that remain moist the entire year. During a very dry

FIG. 10.—Structural characters of *Clivina impressifrons: a*, Ventral aspect of head and mouth parts; *b*, maxilla; *c*, parts of labium; *d*, fore leg; *e*, middle leg; *f*, hind leg. Much enlarged. (Original.)

period they have only a short distance to go below the surface to find plenty of moisture. Professor Webster states that he has observed them in great numbers, floating on the surface of the water in cornfields in Illinois, immediately after heavy rains.[a] Mr. W. C. Stromberg, Galesburg, Ill., states:[b]

At another time a friend of mine turned up a nest of *Clivina impressifrons*. It was in early spring. They were clinging to the underside of a log which was very deeply

[a] Cir. 78, Bur. Ent., U. S. Dept. Agr. [b] Ent. News, vol. 4, p. 150, 1893.

embedded in black soil. In such situations it is rare to find Coleoptera except along the edges, but here there were Clivinas (closely crowded) on a space not larger than one's hand.

REARING EXPERIMENTS.

During the summer of 1906, when the writer's attention was first called to this insect, attempts were made to rear it in confinement. On June 15 several adults were collected and placed in a glass jar that had been previously filled with rich soil, and corn planted therein. No cover was placed on the jar, as the latter curved inward near the top, rendering this precaution unnecessary.

On August 18 the contents of the jar were carefully examined, but no eggs or larvæ could be found. There were 11 adults—not as many, however, as were placed in the jar on June 15. They had tunneled throughout the soil, but the corn had not been attacked. The beetles were still in good condition in December, though no eggs or larvæ could be found in the jar. Whether artificial conditions tend to prolong their lives or whether this is the average length of life could not be ascertained.

October 4, 1906, in a field near Richmond, Ind., a tight box 32 by 8 by 10 inches was let down vertically into the soil, a long box filled with sifted soil being used, so the beetles could go below the frost line if necessary. Some oats, corn, and wheat were planted in this box and about 24 adult beetles were placed inside, after which the box was covered with a closely woven wire screen. They began burrowing into the soil at once, very much after the manner of moles, parting and pushing aside the earth with their strong fore legs. On October 8, 42 more beetles were placed in the box. On June 5, 1907, this box was examined and one adult beetle was found near the top of the cage, just below the surface of the soil. Several others were found at and near the bottom, in their burrows, with their abdomens distended as if containing eggs. These last were apparently dead, though the tissues seemed to be in good condition, but some of them on being dissected were found to contain numbers of a little mite, determined by Mr. Nathan Banks as *Canestrinia* sp. No eggs, larvæ, or pupæ could be found. The fact that comparatively few beetles were present is probably due to their cannibalistic habits and to the presence of the mites, it being since learned that the beetles will devour each other when closely confined or where there is an insufficient food supply.

During the summer attempts were made to rear them in boxes containing soil from the fields where they had been found injuring corn, mixed with decaying wood and growing plants of different kinds, but without success.

In November a box 8 feet long, 3 feet deep, and 2 feet wide, made of tongue-and-grooved boards, was settled in the ground until the top was even with the surface. This was done on the farm of Mr. William G. Baker, near New Paris, Ohio. The box was then filled

with rich, peaty soil from the fields where the beetles had injured Mr. Baker's corn during the summer. About 40 adult beetles were placed in this box, which was then covered with closely woven wire gauze.

May 14, 1908, about 50 beetles were collected and placed in the box prepared the preceding November. During the summer the box was carefully examined, and while a few adult beetles were found there were no eggs, larvæ, or pupæ.

It appeared from these experiments that the insect could not be reared in confinement; so, during the months of July and August the cornfields that had been injured by the Clivina were examined every day, the soil being dug up from a few inches in depth to about 2 feet, and examined very closely. July 23 an adult was found that had just transformed, being still in the earthen pupal cell. This was probably among the first to issue this summer, as none could be found earlier, though patient, careful search had been made. Numbers of small Carabid larvæ were collected for rearing, but all either died or proved to be those of other species. The last week in July full-grown larvæ were found in the fields, which soon changed into pupæ. From this time on larvæ and pupæ could be easily found. Several attempts were made to rear larvæ through to the adults, but without success.

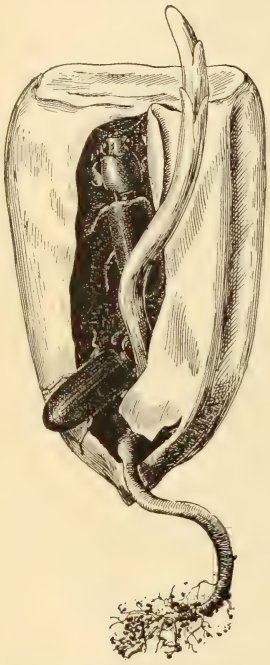

FIG. 11.—Slender seed-corn ground-beetles attacking a kernel of corn; the body of one protruding from the opening. This is the stage at which the major part of the injury is done. Much enlarged. (Original.)

Owing to the pressure of other duties, no further observations could be made on the species during the summer. However, the fields were examined carefully during November, but no larvæ or pupæ could be found. From the above it seems that they begin breeding in May or June and continue to do so through August, September, and probably October.

CHARACTER OF INJURY.

As soon as the corn is planted and starts to germinate the beetles begin to attack it. They usually commence at the germ, often eating the entire contents, leaving only the hull. Sometimes they begin their work before the grain starts to germinate, though it is rare to find them attacking kernels in this manner. As previously stated, they do not always finish a kernel, but as a rule sufficient injury is effected to prevent further growth. As many as five beetles have

been taken from a single kernel, some with part of their bodies protruding from the opening (fig. 11). Sometimes the young plant may push through the earth to the surface of the ground and then die, owing to the fact that the kernel has been destroyed and the root system has not developed sufficiently to support it. A plant with two leaves, that has the kernel entirely destroyed, is shown in figure 12.

RECORDS OF DEPREDATIONS.

EARLY RECORDS.

The first record of the plant-feeding habit of this species was in 1890,[a] from Whitley County, Indiana, where germinating seed corn

FIG. 12.—Work of the slender seed-corn ground-beetle. Reduced. (Original.)

was found to be attacked, the beetles starting their work at the germ. This corn was planted on black, swampy soil.

In 1900 Dr. S. A. Forbes[b] states: "This little ground-beetle, about a quarter of an inch long, * * * may receive mere mention as a beet insect, having once been seen by us in small numbers enlarging a small excavation on the petiole of a beet leaf. The same species had previously been seen burrowing freely into seed corn in the ground."

Five years later Prof. R. H. Pettitt, of the Michigan Agricultural College, reported the same character of injury to seed corn from the

[a] Insect Life, vol. 3, p. 159.

[b] Bul. 60, Univ. Ill. Agr. Exp. Sta., p. 484.

vicinity of Trenton, Mich.,[a] having received material with the complaint that "the corn is badly eaten * * * ." These are the only instances on record of the depredations of this beetle previous to the outbreak in Ohio in 1906.

OUTBREAKS NEAR NEW PARIS, OHIO, IN 1906, 1907, AND 1908.

Some time during the first week of June, 1906, Mr. Wm. G. Baker, of New Paris, Ohio, reported that serious injury had been done by a little brown beetle in his cornfield, which was planted on black,

FIG. 13.—A cornfield near New Paris, Ohio, about the first week in July, 1906, showing results of depredations by the slender seed-corn ground-beetle. (From Webster.)

swampy land. Specimens sent to the writer at Richmond, Ind., proved to belong to this species. On the 15th of June a personal examination of the field was made, and the beetles found still working in the replants, as many as five being taken from one kernel. Twenty beetles were counted within a few inches of a single hill. The corn was planted in checks, with three to four kernels to a hill, and in many cases every kernel was destroyed. This field contained about 40 acres, only about 10 to 15 of which were injured, this being the lower part of the field, where the soil was black and peaty. In some places over a third of the corn, replants and all, was missing. Figure 13 shows the condition of the field a few weeks later.

[a] Bul. 233, Mich. St. Agr. Coll. Exp. Sta., p. 50, figs. 51, 52.

On June 7, 1907, Mr. Baker's field was examined, corn having again been planted in the same field. The first planting of the field was made during the first week in May, and it was replanted about May 20. The field was flooded by heavy rains after each planting. Mr. Baker thought the cool, wet weather was responsible for the poor stand, but as he had never examined into the cause, it is very probable that the ground-beetle exacted its usual toll. The field was then planted for the third time, about the middle of June. Very little of this last planting was injured. It seems that, as a rule, corn planted about the middle of June in this locality is not troubled to any great extent. Experimental plantings made in these fields during the summers of

FIG. 14.—Same field as in figure 13, about the first week of July, 1908, showing results of combined work of the slender seed-corn ground-beetle and cutworms. (Original.)

1906 and 1907 were rarely disturbed, though there were plenty of beetles abroad at the time. No other reason can be assigned for this, except that early in the season the beetles, being ordinarily carnivorous and finding animal food scarce, turn their attention to the palatable corn, whereas later, with animal food plentiful, they do not molest the corn.

May 14, 1908, Mr. Baker's fields were examined and the beetles found to be quite abundant, often as many as 30 to the square yard being found. Corn had not been planted up to this date, but the ground-beetle did considerable injury to this field later. Cutworms, probably *Agrotis ypsilon* Rott., and the beetles together destroyed at least 50 per cent of the corn on the lower part of the field, fully one-half of this being the work of the beetles. Figure 14 shows the condition of the field about the first week in July.

OUTBREAKS IN KANSAS.

Prof. F. M. Webster[a] states that in 1906 Prof. E. A. Popenoe, of Manhattan, Kans., called his attention to two instances where very serious injury had been done in cornfields in the southeastern part of the State, specimens having been sent with each report. Professor Webster stated also that there were numerous complaints in Kansas during that year of corn not germinating and of failures to get a stand on low, swampy land. The greater part of this injury was probably caused by the ground-beetle.

A great many reports of injury are never investigated, it usually being taken for granted that the depredations are caused by wireworms or some other well-known pest, while a large part of the injury is probably due to the ground-beetle.

REPELLENTS APPLIED TO SEED.

As it is a well-known fact that some odors are offensive to insects, a series of experiments was conducted in order to learn if the seed could be treated with some odorous preparation that would repel the attacks of this pest, and, at the same time, be cheap and easily applied. It was decided to use a liquid, as any form of powder or paste would increase the size of the kernel appreciably so that it would not readily pass through a planter. Several heavy oils having odors more or less repellent to insects were selected, as it was believed that these latter would remain longer in the soil after the treated seed was planted. Oils of lemon, cajeput, citronella, wormseed, and mustard, and carbolic acid were used. The oils were diluted to 10 per cent solutions in wood alcohol and applied at the rate of 3 ounces to a gallon of corn. Carbolic acid was diluted in water to a 3 per cent solution and applied at the same rate. The liquids were poured over the corn, which was then stirred vigorously so that each kernel would be completely coated. In planting the checks, all the corn was removed from the planter and the latter filled again with fresh, untreated seed.

EXPERIMENTS IN 1908.

Mr. Wm. G. Baker, near New Paris, Ohio, whose fields had been so badly affected, consented to have the experiments on his farm. Each plat consisted of four rows across his field in the worst infested area. The beetles were very abundant, as many as 30 to the square yard often being found. The numbers of the several plats and the oils with which the seed in each was treated are as follows:

Plat 1, oil of lemon; plat 2, oil of cajeput; plat 2*a*, check (not treated); plat 3, oil of citronella; plat 4, oil of wormseed; plat 4*a*,

[a] Cir. 78, Bur. Ent., U. S. Dept. Agr., 1906, p. 5.

check (not treated); plat 5, oil of mustard; plat 6, carbolic acid. The plats were planted May 21, 1908.

All plats were examined on June 1, 2, and 3, 1908. Every hill that contained no live plants, or that had only one plant, was dug up and examined carefully. Two hundred hills in both the experimental and check plats were inspected. The results are summed up briefly in the following table:

TABLE I.—*Results of experiments in treating seed-corn with repellent oils to ward off attacks of the slender seed-corn ground-beetle.*

Plat No.	Number hills examined.	Destroyed by Clivina.		Total.	Destroyed by other pests.		Total.	Per cent affected by Clivina.	Per cent affected by other pests.
		Number hills entirely destroyed.	Number hills with only 1 plant.		Number hills entirely destroyed.	Number hills with only 1 plant.			
1	200	11	8	19	25	27	52	9.5	26
2	200	8	11	19	15	42	57	9.5	28.5
2*a*	200	11	21	32	28	30	58	16	29
3	200	7	11	18	21	35	56	9	28
4	200	12	16	28	36	49	85	14	42
4*a*	200	10	20	30	21	38	59	15	29.5
5	[a] 200								
6	200	10	12	22	21	20	49	11	24.5

[a] In plat 5, a very large percentage of the seed did not germinate and it is to be inferred that the kernels were injured by the oil, therefore this plat was not included in the table.

No attempt was made to ascertain the number of hills destroyed by each individual pest other than the Clivina. A cutworm, probably *Agrotis ypsilon*, caused a large amount of injury. Wireworms and the seed-corn maggot were also responsible for a part of the trouble. The oil of wormseed probably injured the kernels, as a much larger number of plants in plat 4 were missing than in some of the others.

EXPERIMENTS IN 1909.

After looking over the results of experiments conducted during the year 1908 it was decided to use the oils of cajeput, citronella, and lemon, as these promised the best results. Two small plats (Nos. 5 and 6) were planted later than the others, one (No. 6) with and the other (No. 5) without fertilizer, the fertilizer being placed directly on the corn.

The plats were in the same place as those of the year 1908, and conditions were the same as regards the size of the plats and the quantities of materials used. The treatments given the several plats were as follows: Plat 1, oil of cajeput; plat 2, oil of citronella; plat 3, oil of lemon; plat 4, check (not treated); plat 5, 95 hills planted June 2 (unfertilized); plat 6, 93 hills planted June 2 (fertilized). Plats 1 to 4 were planted May 22, 1909.

Plats 1, 2, 3, and 4 were examined June 5 and 7, and plats 5 and 6 examined June 14. The same plan that was used last year was adopted. The following table gives a brief summary of the results:

TABLE II.—*Results of experiments in the treatment of seed corn to ward off attacks of the slender seed-corn ground-beetle.*

Plat No.	Number hills examined.	Destroyed by Clivina.		Total.	Destroyed by other pests.		Total.	Per cent affected by Clivina.	Per cent affected by other pests.
		Number hills entirely destroyed.	Number hills with only 1 plant.		Number hills entirely destroyed.	Number hills with only 1 plant.			
1	200	8	10	18	.....	46	46	9	23
2	200	20	14	34	.....	24	24	17	12
3	200	17	18	35	.....	24	24	17.5	12
4	200	5	16	21	.....	13	13	10.5	6.5
5	95	5	7	12	3	9	12	12.6	12.6
6	93	5	11	16	8	10	18	17.4	19.3

The last two plats (5 and 6) should not have been planted until about June 10. Normal results could not be expected from such small plantings, as the beetles were no longer working on the larger corn; consequently the percentage of beetles to the hill in these plats must necessarily have been much larger than in the early plantings, when the whole field was planted at once.

In plats 2 and 3 it will be noted that 20 and 17, respectively, are the number of hills mentioned as being entirely destroyed by the Clivina. In both of these plats were found hills that contained no seed, and, as no other cause for this could be assigned, the whole was charged up to the Clivina.

Three checks near the plats were examined, counts being made of the number of hills with only one plant. None of these hills was dug up, as Mr. Baker had replanted the corn, and, of course, this would have interfered with the results.

The following table gives the results of counts in these check areas:

TABLE III.—*Results of examination of check areas of corn as to injury from the slender seed-corn ground-beetle.*

Check number.	Number hills examined.	Number hills with plants entirely missing.	Number hills with only 1 plant.	Total per cent of hills affected.
1	200	24	44	34
2	200	20	36	28
3	200	17	46	31.5

WEATHER CONDITIONS.

The facts concerning the temperature and moisture of the periods over which the experiments, described above, extended were obtained from Mr. Walter Vossler, the local observer at Richmond, Ind. The conditions prevailing at Richmond were very nearly the same as those at Mr. Baker's farm, which is only 8 miles away.

The following table gives the maximum, minimum, and mean temperatures and the rainfall in inches for the months of April, May, and June in 1908 and 1909:

TABLE IV.—*Temperature and rainfall conditions at Richmond, Ind., April, May, and June, 1908 and 1909.*

Month.	Maximum.	Minimum.	Mean.	Rainfall.	Month.	Maximum.	Minimum.	Mean.	Rainfall.
1908.				*Inches.*	1909.				*Inches.*
April	80	24	52	3.76	April	82	20	51	4.68
May	92	29	60	4.97	May	83	32	57	5.37
June	93	39	66	2.69	June	88	47	67	5.74

NATURAL ENEMIES.

A small mite (*Canestrinia* sp.) has been found in great numbers in the abdomen of the adult beetles. As cited on page 19, this mite apparently destroys the beetles, though nothing definite has yet been learned as to the extent of the destruction from this source.

PREVENTIVE MEASURES.

Since the beetles confine themselves to low, swampy land, it would appear at first glance that the remedy is very simple—cease planting such land to corn. However, to a man whose farm consists chiefly of such land, this would seem very poor advice. In the vicinity of Richmond, Ind., corn planted about the middle of June is but little disturbed. From the foregoing it would appear that the greater part of the damage may be avoided by late plantings. This would seem to offer some relief. The class of soil mentioned above usually remains wet and cold until quite late in the spring, but even in case the spring should be a dry one, the extra time could be very well employed in preparing a good seed-bed.

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PAPERS ON CEREAL AND FORAGE INSECTS.

THE CLOVER-ROOT CURCULIO.

(*Sitones hispidulus* Fab.)

By V. L. Wildermuth,
Agent and Expert.

INTRODUCTION.

The genus Sitones includes a large number of species, many of which are known to be more or less injurious to leguminous crops. *Sitones puncticollis* Steph. and *S. lineatus* L., frequently called "pea weevils," have been especially destructive at times to peas, beans, and clover in England as well as on the Continent. In the years 1880 to 1882 and 1883 the crop of peas and beans was practically ruined in parts of England. Miss Ormerod (1883, 1884, 1893)[a] stated that the larvæ were sometimes known as "white maggots" and that in England they obtain their living from the roots of the plants attacked, while the adults feed on the leaves.

In this country only, the flavescent clover curculio (*S. flavescens* Marsh.) has so far proved the most destructive relative of *S. hispidulus*. *Sitones flavescens* depredates on red and white clover, more particularly the latter, and perhaps does a large amount of obscure damage, being widely distributed over most of the United States (Webster, 1886).

While *S. hispidulus* has never been so abundant in this country as totally to destroy a clover crop, yet there is no doubt that injuries that have before been either unnoticed or else laid at the door of some other clover pests, as *S. puncticollis*, *S. lineatus*, or *Phytonomus punctatus* Fab., or even the clover root-borer (*Hylastinus obscurus* Marsh.), by the ordinary observer, were partly the work of the adults and larvæ of this beetle.

From the history of other species of insects that have been imported into this country, and from the fact that late in November, 1909, at two localities, viz, Corning, N. Y., and Marion, Pa., the adults were

[a] See Bibliography, p. 38.

found to have practically eaten up the foliage of clover plants, there is reason to believe that this one may become destructive to the clover crop in future years.

Up to the year 1909 nothing was known regarding the habits of this species in America. Adults were found by Mr. J. A. Hyslop, of this Bureau, early in April, but as Mr. Hyslop was almost immediately thereafter detailed to investigations on the Pacific coast, the writer continued during the remainder of the year the life history study begun by him and succeeded in following out the complete life cycle. The writer is greatly indebted to Prof. F. M. Webster, in charge of cereal and forage insect investigations in the Bureau of Entomology, for his kind direction of the work and for his assistance in the preparation of the manuscript.

HISTORY OF THE CLOVER-ROOT CURCULIO IN FOREIGN COUNTRIES.

The clover-root curculio appears to be a native of Europe, originally described by Fabricius (1776) as *Curculio hispidula* and reported by him as inhabiting aquatic plants in the neighborhood of "Kilia." This description seems to have been drawn up prior to 1776. Later Germar (1824) placed it in the genus Sitones and reported it among others of this genus as occurring in meadows, along roadsides, and under stones.

In 1831 Stephens stated that the species occurred in abundance on sandy heaths and moist meadows in some half dozen different places in England.

Schoenherr (1834) reported it as being found in northern and temperate Europe. He also described a species found in "Tauria" as *S. hæmorrhoidalis*, which was later, in 1864, determined by Allard, in his "Classification of the Genus Sitones," as *S. hispidulus* of Germar. At this time Allard stated that *S. hispidulus* was very common all over Europe, as he had received specimens sent by Motschulsky from Holland, Hungary, Caucasia, Poland, central Russia, and eastern Siberia. From this and from Stephens's British report it will be seen that it was even at that time widely distributed throughout Europe, England, and parts of Siberia. This insect has not attracted so much attention as an economic species in Europe as have others of this genus, especially *S. lineatus* and *S. puncticollis*, but Brischke (1876) made some interesting observations on its destructiveness to clover in the vicinity of Dirschau, western Prussia. He found a clover field there of one year's standing overrun by insects. The leaves were badly eaten and the roots brown and dried up. Upon digging up the earth, he found, among the various larvæ and pupæ, several larvæ and a pupa of a Curculionid which afterwards proved to be those of *Sitones hispidulus*. The larvæ were found to feed on

clover roots and the pupæ were concealed in small earthen cells in the ground, the latter requiring only a short time for development, when the adults began their depredations on the remaining clover leaves. It will thus be noted that its record would seem to show that it may become destructive in America.

HISTORY OF ITS OCCURRENCE IN AMERICA.

Although it has, since the middle of the last century, been widely distributed over Europe and long before that time was very common in England and parts of Europe, yet it was evidently not introduced into America until much later. The first specimen was collected by Le Conte at Long Branch, N. J., in the year 1876, about the roots of grass growing on sand dunes (Hamilton, 1894). During subsequent years its appearance was also noted and collections made at various places in New Jersey, and in 1886 Mr. E. A. Schwarz found it at Piney Point, Md., while three years later it made its appearance in large numbers in the city of Washington, D. C., being found there on both red and white clover on the White House lot by Mr. Henry Ulke (Schwarz, 1889).

Dr. F. H. Chittenden, of this Bureau, found the species very abundant in Washington, D. C., in 1891, and in the spring of 1896 he found the beetles on clover, many of them in copula, on the Department of Agriculture grounds, but after that time he was able to find them only in limited numbers. Collections made since the early observations of Mr. Schwarz and others show the species to be gradually moving westward. In 1894 specimens were collected by the late Dr. John Hamilton at Pittsburg, Pa. (Hamilton, 1894). In 1906 Mr. W. J. Phillips collected one specimen with wheat sweepings at Richmond, Ind., and in the spring of 1908 the writer found both the larva and adult very plentiful at Groveport, near Columbus, Ohio. A specimen was also secured at Newton-Hamilton, Pa., during the past summer, and later in the season a few specimens were collected at Watertown and Clyde, N. Y., and at Vicksburg, Pa.; while at Corning, N. Y., and at Marion, Pa., the species were found in numbers large enough to be a decided detriment to the clover crop. As many as two dozen adult beetles were found at the base of a single plant at Corning, N. Y., and practically all the clover plants in a mixed clover and timothy meadow had at least one-half to two-thirds of the foliage eaten away. At Marion, Pa., the beetles were about as numerous as at Corning, N. Y., and in a 16-acre clover field from two to six beetles were found at the base of every plant, while the damage done was readily noticeable. The damage, of course, would be more apparent at this time of the year, for the cold weather had already checked the growth of the clover plants and enabled the

beetles to make a considerable showing. Specimens were collected at Old Orchard Beach, Me., between 3 and 4 p. m., September 11, 1909, by Mr. C. A. Davis. At this time the beetles were crawling over the sand along the wave line; the tide was rising and the wind was light and offshore. During the summer of 1909, also, adults were found in an alfalfa field, near Pullman, Wash., by Mr. J. A. Hyslop.

SEASONAL HISTORY.

This insect hibernates in the adult form, hiding itself no doubt under rubbish and leaves close to the ground. During the last week of November, 1909, adult males and females were found at Watertown and Corning, N. Y., apparently hibernating. They were lying on the ground under and among the dead leaves and stems of the clover plant. Hibernating individuals begin to die off about the latter part of May or first of June. Miss Ormerod, in her report for 1882, quotes Mr. Cluttenbuck as saying that he found adult *Sitones puncticollis* and *S. lineatus* hibernating in barley, oats, and wheat straw. He says, "We traced the sometimes total loss of the crop of Trifolium to this source, inasmuch as we found the insect in the top joint of the stubble, among which we usually drilled the crimson clover (*Trifolium incarnatum*) without plowing." Since the work and habits of *Sitones hispidulus* are so very similar to those of *S. lineatus*, it seems probable that it may hibernate in similar places.

The adults come forth with the first warm days of early spring, and the female very soon begins oviposition. Adults were observed abroad in large numbers by Mr. Hyslop in a small clover field near Grant road, District of Columbia, on the 1st of April, 1909, and when collected in vials they immediately deposited eggs. On May 4 almost fully developed larvæ were found by the writer on clover roots at Grant road. Eggs for these must have been deposited during the latter part of March.

The female deposits promiscuously a large number of whitish eggs on the leaves and ground, or even on the side of the cage when confined. In the field eggs were found adhering to the lower leaves of both red clover and alfalfa. Within less than a day these eggs change in color to a shining black. It is very probable, however, that in the natural state the eggs are usually deposited at or near the surface of the ground. The egg period is 13 days in duration. The larvæ immediately after hatching go down into the ground. Great trouble was experienced in getting eggs to hatch in rearing cages, and it seems from this that there may possibly be some other as yet unknown condition entering into egg deposition in the field.

The adult beetle endeavors to escape injury or capture by feigning death. If a clover plant upon which this beetle is resting be touched, the beetle drops to the ground and lies there an inactive and almost invisible object. It is only when in motion that one is able to see it readily, since its color harmonizes so well with its surroundings.

The larval period varies from seventeen to twenty-one days, the latter being apparently nearer the normal.

The pupal stage is passed in an earthen cell, which is oval in outline, about three-sixteenths of an inch (5 mm.) long, and half as large in diameter. The time required for the pupal stage is from eight to ten days, easily determined independently of the other two stages by collecting nearly mature larvæ in the field and rearing them to adults.

The larval period was determined by getting the combined length of the egg, larval, and pupal periods and subtracting from these the number of days required for the egg and pupal stages. This method was followed because of the difficulty experienced in getting the newly hatched larvæ to live after being transferred from the vial in which the eggs were hatched to a clover plant on which they could feed, and also because of the fact that the more fully developed larvæ, when disturbed to any extent, nearly always died. Thus, to avoid this, a record was kept of the day of egg deposition in a certain cage and then the beetles were removed and the cage left undisturbed but watched carefully until adults appeared. The time required for this was from thirty-eight to forty-three days, thus making from seventeen to twenty-one days for the larval stage.

Miss Ormerod (1882) has found that in England *Sitones lineatus* and *S. puncticollis*, two closely allied species, have a fall brood. Mr. R. W. Christy, corresponding with Miss Ormerod, stated that as late as October 21 he was unable to find larvæ of *S. puncticollis*, but that during the month of November they were in abundance; while Prof. F. M. Webster, in Indiana (Webster, 1886), has made the same observation in regard to *S. flavescens*. Thus it seemed probable that a fall brood might also occur in *S. hispidulus*, but subsequent observation proves that in the neighborhood of Washington this is not the case.

On September 23 the writer made a thorough but unsuccessful search in a field of clover near Grant road, District of Columbia, for the larvæ of this insect. Adults were found in abundance around the clover crowns, but when placed in confinement these failed to deposit eggs. However, a number of females collected October 7 deposited a dozen or more eggs during the following night. From this time on collections were made every ten days and on each occasion, when placed in vials and left overnight, the females depos-

ited eggs. Of the several hundred eggs collected by this method, however, only two or three hatched. On November 4 the writer, while searching on the grounds of the Washington Monument, at Washington, D. C., found an egg evidently belonging to this species, which, however, failed to hatch. Since the investigation of clover roots at various intervals during October and November failed to reveal any larvæ, it seems certain that the second or fall brood is wanting in this locality. These observations fail to explain the reason for the deposition of eggs in vials. However, during the last week in November, while the writer was on an inspection trip through New York and Pennsylvania, an opportunity was afforded him for collecting a large number of beetles, all of which were apparently in the hibernating stage. These, when taken to a warm room, deposited eggs almost immediately. The facility with which the eggs were deposited in vials may then be accounted for by the fact that these females were just ready to deposit eggs and only awaiting a warm spring day to carry out this work; therefore, on being taken into a warm room the proper degree of temperature was afforded and egg deposition immediately followed.

FIG. 15.—The clover-root curculio (*Sitones hispidulus*): Adult. Greatly enlarged. (Original.)

DESCRIPTIONS.

THE ADULT.

The adult (fig. 15) is a small, black, hard-bodied beetle, from 3 to 5 mm. in length and from 1.25 to 2 mm. in breadth. It has a short head and a general, deeply punctured appearance on the surface of the head, thorax, and elytra. It was described by Fabricius (Paykull, 1800) as follows:

[Translation.]

Head black with fuscous scales. Beak short, concave. Antenna slightly longer than the head. Base rufous. Apex ashy. Eyes large, deep-set. Thorax longer than broad, convex, almost cylindrical, black. Below obscure, ashy scales; above deeply punctured fuscous scales. Ashy scales in the parallel longitudinal lines. Middle one shortest. Scutellum less ashy. Elytra black. Scales densely fuscous and less ashy. Not as wide as thorax but twice as long, convex, punctate-striate, with series of erect, rigid white hairs between the striations. Wings white, hyaline. Breast and abdomen black, with fuscous-rufous scales. Feet rufous. Femora fuscous-ashy, unarmed. As broad as *Curculio hirsutus* but not quite so long.

THE EGG.

The egg (fig. 16), as observed by Mr. J. A. Hyslop, is very slightly ellipsoidal, almost spherical, and slightly granular, measuring 0.36 mm. in diameter; white when first deposited (fig. 16, *a*), but turning jet-black after twenty-four hours (fig. 16, *b*.)

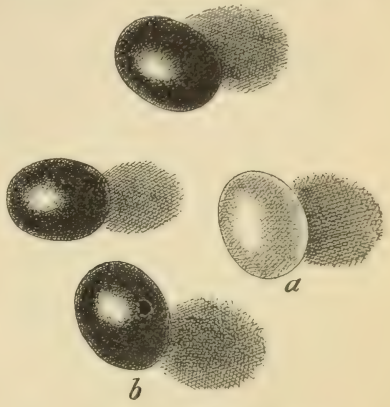

FIG. 16.—The clover-root curculio: *a*, Egg, immediately after oviposition; *b*, egg, one day after oviposition. Greatly enlarged. (Original.)

THE LARVA.

The newly hatched larva is 0.68 mm. in length by 0.18 mm. in breadth and white. The head is light chocolate, the posterior emarginate portion very light, and the sides darker. The head is very prominent, and cordate, 0.16 mm. in length by 0.19 mm. in breadth, the posterior portion deeply emarginate. The abdomen bears black hairs averaging 0.17 mm. in length.

The full-grown larva (fig. 17) is 5 mm. in length and 1.3 mm. in breadth. It is white, with a tinge of yellow. The head is light chocolate, 1 mm. in length by 0.85 mm. in breadth. When found in a natural condition the fresh specimen has a purplish tinge, apparently due to the contents of the alimentary canal.

FIG. 17.—The clover-root curculio: Larva. Greatly enlarged. (Original.)

THE PUPA.

The pupa (fig. 18) is 4 mm. in length, almost white, with a slight tinge of yellow on the dorsal abdominal area. Each segment of the abdomen bears a row of dark hairs and posteriorly at each side of the terminal segment are two very prominent, dark spines, with a secondary spine on the outside of each. On the fourth day after pupation the eyes turn reddish brown and on the ninth day the mandibles become the same color.

FIG. 18.—The clover-root curculio: Pupa. Greatly enlarged. (Original.)

FEEDING HABITS.

The larvæ of this beetle feed on the roots of all the plants mentioned as food plants. The smaller, more tender, or fibrous roots are eaten by the younger larvæ, which, as they become more mature, attack the larger roots. Large cavities are eaten along the main roots, and often these are in the form of a groove containing the feeding larva (fig. 19, *a*). An examination of clover roots, made on September 23, showed clearly the after effects of the work of the larvæ. The roots were eaten at various places, some of them appearing as though the whole surface had been eaten off, the roots being scabby and brown, the damage having evidently been done during late spring or early in the summer.

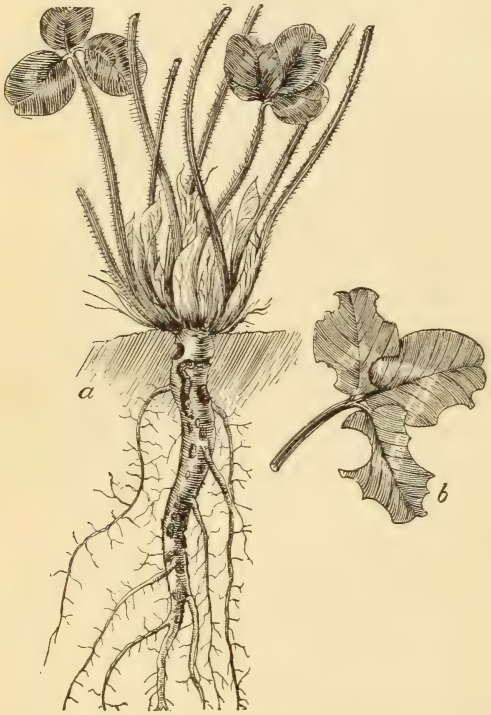

FIG. 19.—The clover-root curculio: *a*, Red clover root showing effects of attack by larvæ; *b*, red clover leaf showing work of adult beetles. About natural size. (Original.)

The adults feed on the leaves, eating out irregular patches from the margin of the leaf. (Fig. 19, *b*.) They are not as hearty eaters as some of the allied species of beetles that live on clover, and hence their work is not so noticeable, except when the beetles have developed in excessively large numbers, as was the case at Corning, N. Y.

FOOD PLANTS.

While the genus Trifolium seems to provide the natural food plants of this insect, there are reasons for believing that others may in future be added. The species *hispidulus*, when first observed in this country by Doctor Le Conte, was reported by him as present around the roots of grasses growing on sand dunes. Stephens in 1831 reported it in England as being abundant on sandy heaths, which were no doubt grown up with grass.

The writer in the spring of 1908 found the larvæ in large numbers in a blue-grass pasture. These were to all appearances feeding

partly on blue-grass roots, as the only clover present was *T. repens*, and this was rather scattering in the field. From this it would seem that some of the grasses may be host plants.

Of the genus Trifolium, red clover appears to be the most common choice as a food, while white clover (*T. repens*), crimson clover (*T. incarnatum*), and alsike clover (*T. hybridum*) are all fed upon to a greater or less extent by both the adults and larvæ. Alfalfa (*Medicago sativa*) seems to be a common food plant for both larvæ and adults. On June 17 the writer collected numerous larvæ from among alfalfa roots in a field at Somerset Heights, Md., and while sweeping over a field of alfalfa with an insect net at Muirkirk, Md., on April 28, experienced no difficulty whatever in securing from six to eight adults with each sweep of the net. It seems likely that, with the increasing acreage of alfalfa, this insect may become a destructive pest and also menace this crop. The fact that alfalfa is always left standing on the same land for a fairly long period, from three to six years, may greatly accelerate the rapidity with which the insect will be able to increase in numbers.

NATURAL CHECKS.

The larva was found to be attacked by a fungus, one of the Entomophthoræ, which no doubt assists in keeping the insect in check. The larvæ, because of their sluggish movements, might be easily captured and fed upon by predaceous beetles, but the fact that the larvæ and pupæ are subterranean in their habits is a semiprotection from parasitic insects as well as from many predaceous enemies. No Hymenopterous or Dipterous parasites were observed.

BIRD ENEMIES.

The Biological Survey, in its work on the food habits of birds, has found that the following birds feed upon the adults of this beetle: Upland plover (*Bartramia longicauda*); killdeer or killdee (*Oxyechus vociferus*); ruffed grouse (*Bonasa umbellus*); broad-winged hawk (*Buteo platypterus*); flicker (*Colaptes auratus*); nighthawk (*Chordeiles virginianus*); chimney swift (*Chætura pelagica*); wood pewee (*Myiochanes virens*); crow blackbird (*Quiscalus quiscula*); meadowlark (*Sturnella magna*); Lincoln finch (*Melospiza lincolni*); song sparrow (*Melospiza melodia*); chipping sparrow (*Spizella passerina*); and the white-throated sparrow (*Zonotrichia albicollis*).

Of these birds the chimney swift and song sparrow were found to be the greatest feeders on the insect, as many as fifteen adult beetles being found in the stomach of one chimney swift, while but few less were found in stomachs of song sparrows.

PREVENTIVES AND REMEDIES.

Up to the present time the depredations of this beetle have apparently been too limited and inconspicuous to call for investigations along the line of remedies and preventives.

The system of short crop rotation, so advantageously employed in the eastern United States, has no doubt assisted in limiting their number. Clover is, as a rule, grown for only a short period over the same piece of ground and thus no opportunity is afforded for the continuous development of the pest. On the other hand, the plan of allowing alfalfa to stand on the same ground for a period of from three to six years would probably facilitate the increase of the insect.

From the nature of the work of the beetles it is very hard to suggest any remedy that would destroy the beetle and not produce more or less damage to the clover crop. Clover fields might be burned over during the winter months, when the ground is frozen, without injuring the plants to any extent.

The fact that the larvæ are easily killed when disturbed suggests a possible remedy in harrowing or cultivating the ground by some method in early spring and thus destroying a certain percentage of the larvæ, but for this to be wholly effective a large amount of the clover would necessarily also be damaged and possibly killed.

As shown before, natural enemies, such as fungous diseases and birds, have without a doubt contributed largely toward holding the insects in check.

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PAPERS ON CEREAL AND FORAGE INSECTS.

THE SORGHUM MIDGE.

(*Contarinia* [*Diplosis*] *sorghicola* Coq.)

By W. Harper Dean,

Agent and Expert.

INTRODUCTION.

Sweet sorghum, aside from its use in making molasses, ranks as one of the most important forage crops grown in the United States. It is highly prized as a green food for cattle and horses and is well adapted to entering the composition of silage. Several crops are sometimes produced during the season, the last fall crop generally being cured as a dry winter fodder. In Louisiana and Texas, while this crop is grown practically over the entire States, no large areas are cultivated, but it is found in small, isolated blocks ranging in extent from one-fourth acre upward.

In parts of a great many sorghum-growing States the seed do not mature a profitable crop, and while this may be attributed, and rightly, too, to a number of causes, it is safe to say that in the majority of cases the sorghum midge, *Contarinia sorghicola* Coq. (figs. 24, 25), is directly responsible for the damage to the seed.

Such destructive agencies as various pathological diseases, the English sparrow, the moth *Nigetia sorghiella*, and the rice weevil (*Calandra oryza* L.) all help to curtail the number of sound, mature seed produced, but by far the most destructive agency that has been observed by the writer is this minute fly, the midge, which breeds in swarms from the time the first heads have bloomed until the last have been killed by cold.

An examination of damaged seed in sections where the midge is known to occur will reveal the minute larvæ of this fly lying close alongside the ovary, which is blackened and shriveled (fig. 20, *b*), while the ovary in healthy mature seed is plump and white (fig. 20, *c*).

Injury by the English sparrow can be readily distinguished upon examination from injury by other agents. Such heads have a shat-

tered, frayed appearance, resulting from the seed being torn from the outer glumes (fig. 20, *a*), while those seed injured by the midge have a dark, flattened appearance (fig. 20, *b*), and minute pink and white larvæ can be seen, sometimes as many as six of them, lying close alongside the ovary. These are the larvæ of the sorghum midge.

HISTORY OF THE SORGHUM MIDGE IN AMERICA.

The earliest reference to the sorghum midge occurs in 1895 in a report by Mr. D. W. Coquillett, of the Bureau of Entomology, United

FIG. 20.—*a*, Sorghum head partly destroyed by English sparrows; *b*, sorghum head infested by the sorghum midge (*Contarinia sorghicola*), showing characteristic flattened appearance of spikelet; *c*, sorghum head with matured healthy seed. (Original.)

States Department of Agriculture, in which he described the appearance of several heads of sweet sorghum received from Dillburg and Montgomery, Ala. These heads contained a large number of seed which had failed to mature and which had apparently been destroyed by the larvæ of some species of Cecidomyiidæ. However, only the empty pupal skins attached to the spikelets of the seed were present, so no clue to the identity of the species was given. This note was

made October 2, 1895, and nothing further was heard from this insect until September 26, 1898, when Mr. Coquillett received a second lot of heads from College Station, Tex. The latter contained the larvæ of this insect, as well as a large number of the flies themselves. Mr. Coquillett decided that these belonged to an undescribed species, and forthwith he published the first technical description of the midge under the name *Diplosis sorghicola*, new species.[a]

In a special article in Science, published January 17, 1908, Prof. Carleton R. Ball, of the Bureau of Plant Industry, United States Department of Agriculture, discussed his experiments with the midge in Louisiana and Texas during the spring of 1907. These experiments resulted from an investigation of the causes of sterility of sorghum seed.

Working under the direction of Prof. Wilmon Newell, of the State Crop Pest Commission of Louisiana, Mr. R. C. Treherne conducted a systematic investigation of the midge during the spring and summer of 1908, and later published a brief summary of the results obtained.[b]

Prof. Glenn W. Herrick, entomologist at College Station, Tex., contributed to the information on this insect in an article published in Entomological News.[c]

At the time when official recognition was taken of the importance of this insect by the Bureau of Entomology, Prof. F. M. Webster, under whose department this investigation fell, was unable to begin the work through lack of available field assistants. In order that no time should be lost in making this beginning, however, Professor Webster arranged with Prof. Wilmon Newell, of the State Crop Pest Commission of Louisiana, to pursue a cooperative investigation until such time as he could relieve him of the bulk of the work. Accordingly, Professor Newell assigned one of his assistants, Mr. R. C. Treherne, to the work, which was systematically conducted during the spring and part of the summer of 1908 until the writer was assigned the problem under the direction of Professor Webster. On July 25, 1908, Mr. Treherne discontinued the work and at that point it was taken up by the writer at Baton Rouge, La.

Professor Newell kindly allowed the writer unlimited access to his most complete laboratory and offices, and these were used as headquarters during the Louisiana investigation. In many other ways, too numerous to mention, he contributed to the progress of the work. It is therefore evident that but for this hearty coopera-

[a] Bul. 18, n. s., Div. Ent., U. S. Dept. Agr., p. 82, 1898.

[b] Thirty-ninth Annual Report of the Entomological Society of Ontario, 1908.

[c] Entomological News, vol. 20, No. 3, pp. 116–118, pl. 7, Mar., 1909.

tion of Professor Newell the investigation of the sorghum midge by the Bureau of Entomology would have been much delayed.

Acknowledgment is due Prof. C. S. Scofield, of the Bureau of Plant Industry, who rendered valuable assistance to the investigation in Texas by placing the experiment farm near San Antonio, Tex., at the service of the writer for growing varieties of sorghum used in the experiments.

During 1908, in Louisiana, and 1909, in Texas, the investigation was continued, and the results constitute the basis for this report.

DISTRIBUTION.

The distribution of the sorghum midge in the United States, as given under this chapter, does not necessarily include all infested territory.

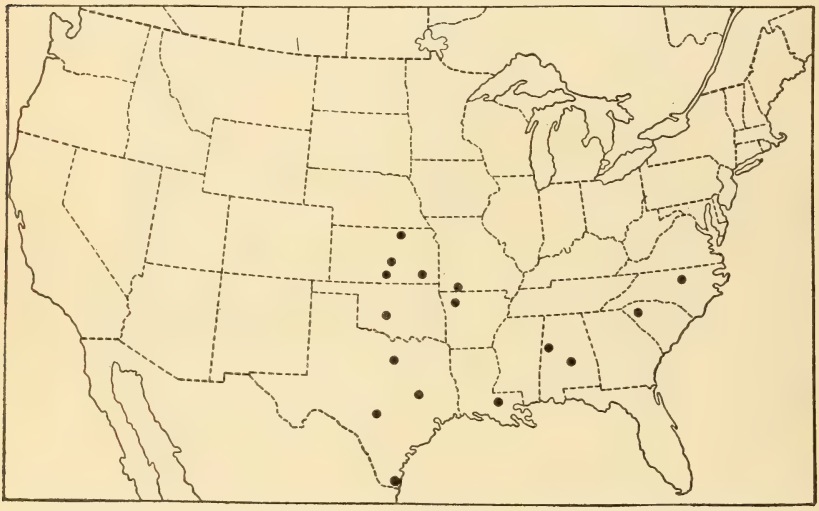

FIG. 21.—Base map showing present distribution of the sorghum midge. Dots indicate infested localities. (Original.)

Through examinations made in person in the fields or through the actual rearing of the midge from heads received from various sections, these data have been collected and will of course be added to from time to time. The sorghum midge is not known to exist west of the one hundredth meridian, and its extreme southern point of distribution in the United States is Brownsville, Tex. The accompanying map (fig. 21) shows the general distribution as known at this writing.

INVESTIGATIONS CARRIED ON IN LOUISIANA AND TEXAS DURING 1908 AND 1909.

During the years 1908 and 1909 the writer pursued the investigation of the sorghum midge in Louisiana and Texas. These investigations were in the main confined to the field, although certain labora-

tory methods were employed to get at the more obscure phases of the problem.

In Louisiana it was found that, owing to the excessive humidity, infested sorghum heads when brought into the laboratory from the field almost invariably molded and rotted before observations upon the emergence of the adults could be made, and, furthermore, such conditions would not yield true results. For this reason, then—and the same applies to Texas—all records of life history were made in the field upon growing heads and subject to absolutely normal conditions.

In brief, the method employed in the study of the various forms of the midge was to select a number of sorghum stalks in the field whose heads had not broken the boot or protecting sheath and which were therefore not infested by the midge. Over these unbroken heads were placed waterproof paper bags, the tops of which were gathered securely about the stalks well below the head and securely tied with string, to which tags were attached. These bags were allowed to remain over the unopened heads until by observation the latter had broken the sheath and the spikelets were in a condition to receive an infestation by the midge. Then they were removed from the heads, and these were watched until females were actually seen to oviposit within the glumes. When the natural infestation was well under way a note was made upon the small tag attached to the stalk below the head, giving the date and the hour of the first egg deposition. (See fig. 22.)

FIG. 22.—Growing sorghum head, bagged and tagged after natural infestation by the sorghum midge. This method is also practical for protecting seed in the field from damage by the midge. (Original.)

At various times these heads were cut and dissected in the laboratory and the oldest form of the midge found therein recorded,

which gave accurate data upon the time required for the various stages in the life cycle.

It is a matter of regret that this system was not discovered during the work in Louisiana, only one similar method being employed. This consisted in suspending a breeding cage from a small scaffold over the growing head and artificially introducing the adult midges from a bell jar. (See fig. 23.)

In Louisiana great difficulty in these life-history studies arose from the depredations of the Argentine ant (*Iridomyrmex humilis* Mayr).

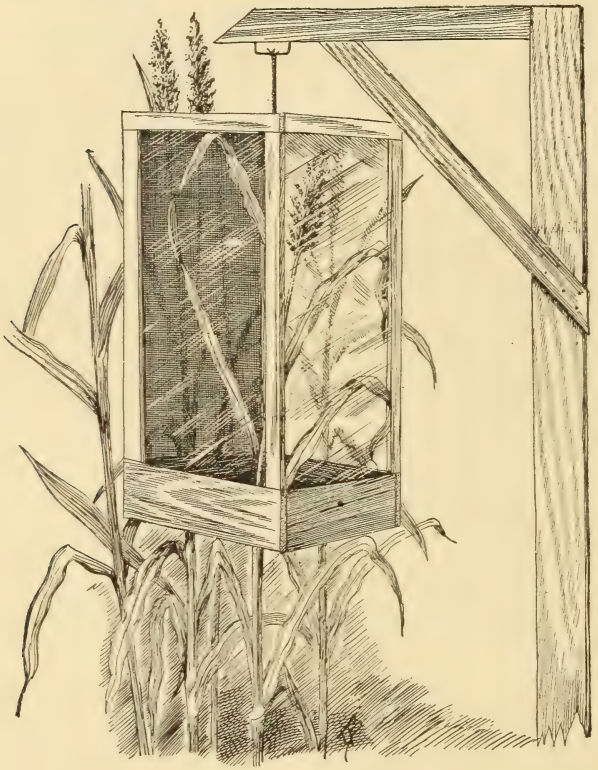

FIG. 23.—Breeding cage suspended over growing sorghum. Three sides of the cage are covered with cheese cloth; the fourth is fitted with movable glass. With this arrangement artificial breeding of the sorghum midge can be observed under absolutely natural conditions. (Original.)

These ants repeatedly gained access to breeding cages in the laboratory and destroyed the results by extracting the midge pupæ from the apex of the spikelet just prior to emergence, and also by capturing the adults which had succeeded in emerging.

HOST PLANTS.

In addition to the many varieties of sweet sorghum, the sorghum midge is known to infest broomcorn, kafir, Johnson grass, and milo.

In one instance the writer reared a single adult from the common foxtail grass (*Setaria glauca*)[a] and Mr. George G. Ainslie has also reared the midge from the grass *Sieglingia seslerioides*.[b]

In the investigation of this problem many varieties of sweet sorghum were observed in their relation to infestation, among which are Early Amber, Gooseneck, Sapling, and Sumac, with some members of the durra group; and while there is some difference in the degree of infestation of these varieties it has not been observed to be sufficiently great to merit the recommendation of any of them as

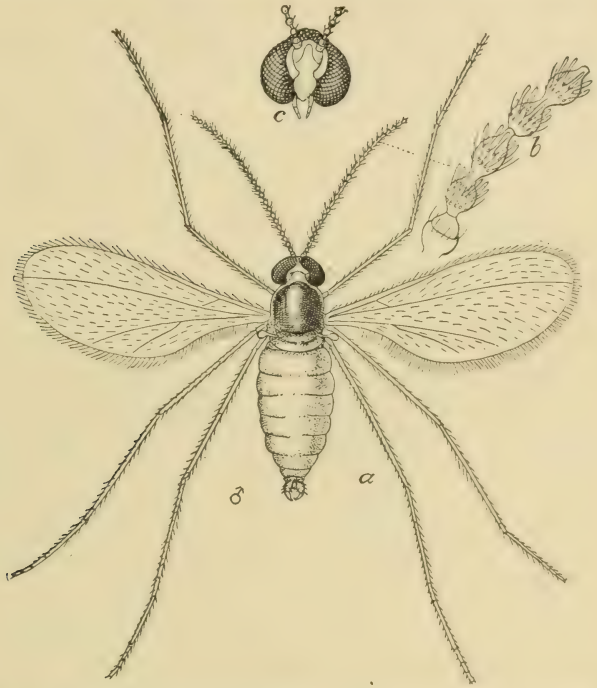

FIG. 24.—The sorghum midge (*Contarinia sorghicola*): *a*, Adult male; *b*, antenna joints of same; *c*, head, frontal view. *a*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

resistant varieties—all being infested to such an extent that they would have failed to produce a profitable crop of seed.

DESCRIPTIONS.

THE ADULT.

The following is the original description of the species by Mr. Coquillett:

Antennæ of the male as long as, of the female almost one-half as long as, the body, in both sexes composed of 14 joints; joints 3 to 14 in the female each slightly constricted in the middle, each except the last one greatly constricted at the apex into

[a] Baton Rouge, La., September 14, 1908.

[b] Clemson, S. C., August 15, August 31, November 3, and September 8, 1908.

a short petiole, a few bristly hairs not arranged in whorls scattered over each joint; in the male, joints 3 to 14 are each greatly constricted, slightly before the middle, and again at the apex except in the case of the last joint, the constricted portions are as long as the thickening at the base of each joint; each of the thickened portions bears a whorl of bristly hairs. In the living insect the head, including the palpi, is yellow, antennæ and legs brown, thorax orange red, the center of the mesonotum and a spot crossing the pleura and enlarging on the sternum black, abdomen orange red, wings grayish hyaline. The first vein reaches the costa noticeably before the middle of the wing; third vein nearly straight, ending slightly below the extreme tip of the wing, the basal portion of this vein, where it joins the first vein, distinct; fifth vein forked slightly before the middle of the wing, its anterior fork ending nearly midway between the tip of the posterior fork and the apex of the third vein. Length nearly 2 mm

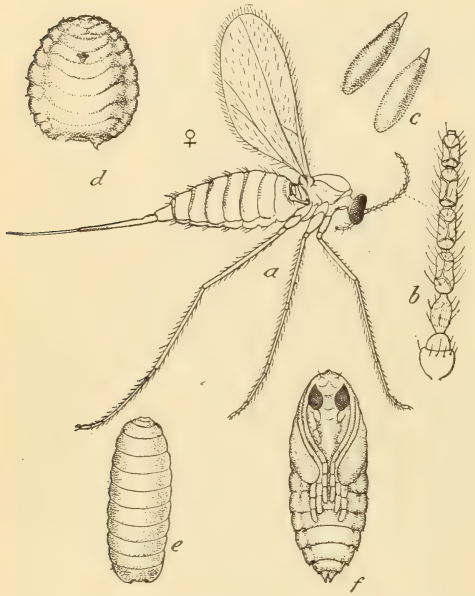

FIG. 25.—The sorghum midge: *a*, Adult female, dorsal view; *b*, antennal joints of same; *c*, eggs; *d*, fully developed larva as found in cocoon, showing characteristic cecidomyiid "breastbone"; *e*, larva in early stage; *f*, pupa. *a*, *d*, *e*, *f*, Greatly enlarged; *b*, *c*, highly magnified. (Original.)

The male (fig. 24, *a*), as indicated in Mr. Coquillett's description, is provided with antennæ which exceed in length those of the female and which differ greatly in the structure of their joints, while on the wing the former characteristic serves to distinguish the sexes; also, the movements of the male are much quicker than those of the female.

The female (fig. 25, *a*) to superficial examination, at rest or on the wing, appears more robust than the male and at the same time her movements are much more deliberate and slow. She is provided with a delicate hairlike ovipositor, capable of great extension during the process of oviposition. Often its length exceeds that of the entire body. The following measurements of average male and female midges serve to illustrate the comparative dimensions of the two sexes:

TABLE I.—*Comparative measurements of males and females of the sorghum midge (Contarinia sorghicola).*

Measurement.	Adult female.	Adult male.	Measurement.	Adult female.	Adult male.
	Millimeters.	*Millimeters.*		*Millimeters.*	*Millimeters.*
Length of body (antennæ excluded)	1.78	1.22	Width of thorax	0.45	0.27
Length of antennæ	.843	1.05	Length of wing	1.87	.85
Length of ovipositor	1.64	.....	Wing expanse	4.19	1.98
Total length	4.36	2.27			

The above measurements are taken from average-sized adults and, while these latter vary considerably, especially in the male, the measurements given represent with a fair degree of accuracy the average comparisons between the two sexes.

THE EGG.

(Fig. 25, *c*.)

The egg is a delicate, elongated, cylindrical structure. One end tapers to a fine hairlike point, which before oviposition is often twice the length of the egg proper. The color is pale pink or yellow. This tapering end of the egg appears to be a special construction, the purpose of which is, at this writing, unknown. The end of the egg proper is capped with a ferrule-like appendage from which, in gradually diminishing diameter, this projection extends. This appendage is not dissolved in xylol, alcohol, or any fluid in which the egg proper is dissolved, and does not appear to be the same material as eggshell. When examined within the abdomen of the female, the eggs are found in an unbroken chain of groups of three or four, the threadlike appendages projecting toward the distal end of the ovipositor and apparently loosely joined at their extremities, so that the appearance suggests small bunches of eggs attached to a common point by the ends of their delicate appendages. When laid, the appendage gradually shrivels and dries until it contracts to a third of its original length or less. The egg is about 0.15 mm. in length.

THE LARVA.

(Fig. 25, *d*, *e*.)

The newly hatched larva closely resembles the egg in appearance, it often being difficult to determine just when the egg stage ceases and the larval stage begins. In color the newly hatched larva runs between a pale yellow and a pale pink. It is uniformly broad throughout the entire body length. As growth continues the color changes from a pale pink to pink, then red, and when full grown it is often deep red. The body to superficial examination appears uniformly cylindrical, but under the microscope is seen to taper perceptibly at the head and posterior extremity. Only after the last molt can the characteristic cecidomyiid "breastbone" (fig. 25, *d*) be distinguished.

Repeated measurements of larvæ in different stages of growth give uniformly regular figures. Table II gives the measurements of a number of larvæ taken from seed at different stages of growth from newly hatched to full grown.

TABLE II.—*Measurements of larvæ of the sorghum midge.*

Larva No.—	Length.	Breadth.	Larva No.—	Length.	Breadth.
	Milli-meters.	*Milli-meters.*		*Milli-meters.*	*Milli-meters.*
1	0.15	0.075	7	0.6	0.3
2	.1804	.082	8	.89	.35
3	.28	.082	9	.903	.35
4	.329	.12	10	1.0	.492
5	.493	.141	11	1.5	.5
6	.573	.25			

While the above examinations do not refer to larvæ of the same generation, they serve to illustrate the gradual growth from the time of hatching until just before transformation into pupæ. These figures can safely be taken as representative of the measurements of a single larva from date of hatching until full grown. In this instance the larval stage covers eleven days.

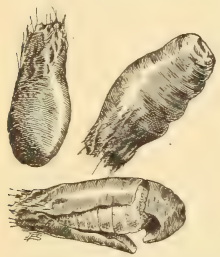

FIG. 26.—The sorghum midge: "Cocooned larvæ," the hibernating form of the midge. Much enlarged. (Original.)

THE PUPA.

(Fig. 25, *f*.)

When newly formed the pupa is uniformly deep red in color, while just before emergence of the adult the head and appendages turn dark and finally black, while the abdomen remains a deep red. There is often a delicate cocoon surrounding the pupa before the latter has worked its way to the apex of the spikelet for the emergence of the adult. It is evident that such are found upon those pupæ derived from "cocooned larvæ." This thin covering is very loosely attached to the pupa and has never been found by the writer after the pupa has left its initial position alongside the ovary.

THE "COCOONED LARVA."

(Fig. 26.)

The "cocooned larva" is closely allied in structure and function to the "flaxseed" of the Hessian fly. The delicate envelope is somewhat elliptical in shape, quite flat, and of a muddy-brown color. It is found close against the ovary itself within the delicate palet. Examined through the microscope the envelope is semitransparent, containing a larva about two-thirds grown and surrounded by a clear protoplasmic fluid. In this form the segmentation of the larvæ is discernible, yet the structures seem faintly outlined and embryonic in contrast to the naked normal larva. The function of the "cocooned larva" is to perpetuate the species over winter and is the

true hibernating form from which the spring pupæ are derived. These enveloped larvæ also appear greatly flattened and are extremely thin and delicate in structure. In addition they are themselves semitransparent, the protoplasmic contents being visibly granular.

LIFE HISTORY AND HABITS.

EMERGENCE.

Emergence of the adults takes place as a rule during the early morning hours during the warmest weather, and later, when the weather turns cool, later in the morning and continuing well into the day. While there is almost a continual emergence in the field from early morning until late in the afternoon, the bulk of emergence occurs as stated, varying with the change of season.

The pupa, having worked its way from the initial position alongside the ovary to the apex of the spikelet, protrudes about two-thirds of its length. The operation of casting off the pupal skin begins almost immediately. The abdomen is seen to twist with a backward and forward motion, the head and thorax likewise performing the same motions until the pupal skin is gradually split open its entire length, along the dorsum or venter, and sometimes both. The skin does not necessarily part in a well-defined line on either the dorsal or ventral surface, but is often torn raggedly over its entire surface. The head of the adult is gradually thrust through the opening, and then finally the entire body. The legs assist materially in this operation by pushing back the clinging pupal skin free from the body. When free, the adult is very moist and weak and clings to the outer glumes for about ten minutes before it has become sufficiently strong and the wings have dried so as to permit flight. About fifteen minutes elapses from the time the adult begins to free itself from the pupal skin until it is on the wing. The cast-off pupal skin remains clinging to the apex of the spikelets. A count of a whole season's emergence, numbering many thousands, fixes the proportion of males to females as three of the latter to one of the former.

COPULATION.

Immediately after drying, the male takes wing and hovers about the seed head, awaiting the appearance of the females. When the latter have emerged, copulation at once takes place, more often before they have sufficiently dried to fly. When the drying process of the female is complete, she begins to oviposit within the seed glumes, and this operation continues until she has laid her quota of eggs, when death follows. The operations of copulation and oviposition are very rapid and are kept up repeatedly until both male and female are dead.

OVIPOSITION.

The process of oviposition, as carried on immediately after emergence and copulation, is short and rapid. The females crawl carefully over a head for a few seconds until they find a spikelet which presents the best adaptabilities for egg laying. Oviposition begins before the flowers appear and continues as long as the glumes remain flexible, probably from five to seven days. When the female has selected the spikelet she takes up a position upon the apex, her abdomen elevated slightly above the tip, and immediately extends

FIG. 27.—Sorghum heads, showing four successive stages in the opening of the sheath or "boot." [a] (Original.)

her ovipositor, pushing it within the spikelet until it is fully extended; then, with a rapid pistonlike motion, she places the egg. It is doubtful if more than one egg is deposited at a time by a single female in a given spikelet. Dissections of glumes observed to have been oviposited in by but one female, and but once, have not, during the writer's investigations, revealed more than one egg.

However, it is no uncommon sight to observe several females follow one another in quick succession, ovipositing within the same spikelet. Numerous examinations of infested spikelets have revealed as many as

[a] See footnote, p. 51.

eight or ten stages of the midge against one ovary, all the stages ranging from unhatched eggs to fully developed pupæ, showing that egg deposition is kept up until the hardening of the glumes at the apex checks oviposition.

Another important phase of egg deposition, which accounts for the irregular emergence of the adults from a head, is that of the long period during which a head is in condition to receive the eggs of the midge. As has already been pointed out, oviposition may continue for several days; this in itself gives rise to a large number of midge forms of different stages of growth on a single ovary.

Again, oviposition continues upon a head from the time the first spikelets are visible through the opening sheath until after the head is entirely exposed. Figure 27 represents four stages of development of the head.[a] About four days are required for the head to completely emerge, during which time the seed have been infested by the midge as fast as they were accessible to her ovipositor.

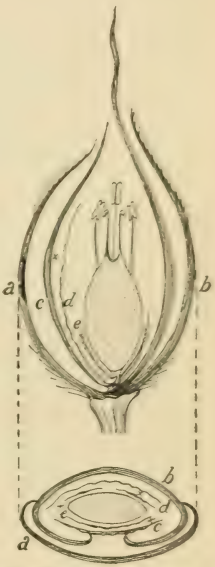

FIG. 28.—Sectional views of the sorghum seed during the flowering stage: *a*, First outer glume; *b*, second outer glume; *c*, inner glume; *d*, second inner glume; *e*, lodicules. X's indicate points at which eggs of the sorghum midge are commonly found. (Original.)

LOCATION OF THE EGG.

The location of the egg (fig. 28) varies, inasmuch as the condition of the glumes varies at different stages of development, and consequently a female ovipositing just before the glumes close would not place her egg as far down as the female ovipositing immediately after the shedding of the blooms. Generally speaking, the eggs are found near the apex of the ovary, but the writer has found them located in practically every part of the inner seed structure. It is therefore dependent upon the stage of seed development as to where the egg will be found. If infested during the flowering stage, the female usually inserts her ovipositor between the first and second inner glumes, and in such cases the egg will be generally found somewhere near the apex of the ovary sticking to one of the glumes. In one instance, at San Antonio, Tex., the writer observed females ovipositing in glumes which had shed the flower and the apices of which were too hard to admit of oviposition at that point. In this case the females were observed to crawl over the glumes and then insert the ovipositor into the crevice formed by the first outer glume

[a] Fig. 27, *b* and *c*, are not normal, owing to the drying of the material before the drawings could be made.

overlapping the second outer glume and at a point midway between the apex and base of the glumes. An immediate dissection of these seeds revealed the eggs situated upon the inner surface of the second outer glume almost in view from a superficial examination. It is extremely doubtful if larvæ hatching under such conditions would find their way to the ovary.

LOCATION OF THE LARVÆ.

When hatched the larvæ immediately make their way to the ovary and are invariably found lying directly against the latter within the delicate palet. Their position remains unchanged throughout growth, their length being parallel to the ovary and the head pointing to the apex of the glumes. The larvæ, expanding their full length close against the ovary, sap the juices. A faint discoloration of the ovary takes place at the point of contact with the larva shortly after the latter has taken its normal position. This discoloration deepens perceptibly as larval growth increases, and during the full-grown stage the larva is set in a tiny depression, caused by the draining of the plant juice by the larva at that point.

LOCATION OF THE PUPA.

The pupa is formed in exactly the same position as has been occupied by the larva during its growth and development. The head is directed toward the apex of the glumes, to which point it works itself preparatory to emergence.

NUMBER OF GENERATIONS.

There are no well-defined broods or generations. From early spring until late fall the midge may be found in any stage from egg to adult.

THE LIFE CYCLE.

The greatest of difficulty has attended the determination of the periods required for the egg, larval, and pupal stages. Under the most careful manipulation newly deposited eggs, when located and examined, invariably shriveled and failed to hatch before the spikelets opened and the eggs were exposed to atmospheric influences; consequently, attempts to watch newly deposited eggs until the date of hatching have been so far unsuccessful. The same difficulties apply to raising larvæ to maturity under artificial conditions. The pupæ, however, are more successfully handled, as exposure to air does not seem to affect their development and the emergence of the adult.

The method finally adopted consisted of permitting heads to become infested under natural conditions in the field, then bagging them, and later dissecting the spikelets at various intervals. Thus, with a large number of heads infested and examined at different periods,

the approximate time required for the three stages was secured. At Baton Rouge, La., the only successful attempt to secure the total number of days in the life cycle gave 23½ days from the time of natural oviposition to the emergence of the adults. This development took place during an average daily mean temperature of 79° F. and an average daily mean humidity of 74.3. In San Antonio, Tex., the development from egg to adult required 14 days during an average daily mean temperature of 84.7° F. and an average daily mean humidity of 67.5. In the latitude of San Antonio, Tex., generally speaking, the egg stage will cover from 2 to 4 days, the larval stage from 9 to 11 days, and the pupal stage from 3 to 5 days, depending upon the temperature and humidity. A very wide range in length of time for the various stages has been recorded, but during the normal temperature and humidity conditions in this latitude from 14 to 20 days are the average.

LENGTH OF LIFE OF ADULT.

In confinement, when no opportunity is afforded for oviposition, the length of life of male and female is approximately 24 hours, while females, when allowed to oviposit, live longer, generally about 48 hours. The length of the life of the female is largely dependent upon the number of eggs she is capable of laying—death following shortly after the egg supply has been exhausted. Females were found upon dissection to contain from a dozen to upward of a hundred eggs.

So far no feeding of adults has been observed. Close observation has failed to reveal a single instance in which either male or female partook of nourishment, their activity being confined solely to copulation and oviposition.

SEASONAL ACTIVITY.

In the spring the midge appears with the first Johnson grass and sorghum, and, as this grass heads considerably before the cultivated sorghum, it may be said that by the time the latter has headed the midge has become sufficiently abundant on the grass to make the first sorghum infestation a heavy one. In the latitude of San Antonio, Tex., the first midges to be found during the season of 1909 were found actively ovipositing in Johnson grass on May 14. At this date the neighboring sorghum had not headed, and it was not until June 19 that the first brood emerged from the sorghum, which puts the date of this first infestation at approximately June 5.

Throughout the entire season the midge is found active upon its hosts; in fact, as long as heading Johnson grass and members of the sorghum family can be found in infested localities the midge is certain to be present also. During the winter, when the activity of the midge has apparently ceased, a few recurring warm days suffice to bring out

the adults in considerable numbers, and as long as there are any heads in which to oviposit they will continue to breed, although without the regularity of the warm season, their development being entirely dependent upon a sufficiently high temperature. On November 25, 1908, the writer discovered, in a field near Grand Prairie, Tex., several stalks of sorghum which had been allowed to stand after the last crop had been harvested. Examination of seed in these heads revealed a number of midge pupæ, which, after remaining in the warm office at Dallas for 24 hours, yielded a number of adults. Later these heads were sent to Washington, where they were kept throughout the winter at outdoor temperature, which was very low, and a careful dissection of these heads during the month of January showed that all the pupæ had transformed into adults during the time the heads were in the heated room at Dallas, leaving nothing but the true hibernating "cocooned larvæ" to carry the species over winter. It appears from this that artificial heat will not develop "cocooned larvæ" that have been found late in the season.

HIBERNATION.

As previously stated, the true hibernating form of the midge is the "cocooned larva." Although naked pupæ derived from normal larvæ can be found during the winter months, this "cocooned larva" is the one form which, if the heads are subjected to extreme cold, will perpetuate the species. Normal pupæ will stand considerable cold, and later, upon being exposed to sufficiently high temperature, will emerge, but the "cocooned larvæ," when once they have been subjected to cold, will remain over winter until spring and produce cocooned pupæ and, later, adults. Therefore we can only say that the sorghum midge hibernates as "cocooned larvæ" and naked pupæ, though the preponderance of the former during the winter is very marked. In addition to the instance cited by the writer at Grand Prairie, Tex., Prof. Glenn W. Herrick records an instance in which, after a freeze sufficient to kill the sorghum and kafir, he brought in infested heads of the latter, from which, after they had been exposed to the temperature of a heated room, adult midges emerged in large numbers. Professor Herrick found that the normal pupæ and larvæ in these heads had not been killed by the freeze.

The occurrence of larvæ upon the seed during the winter months does not indicate the wintering of the midge in this stage, but is attributable to the habit which the sorghum has of continuing to put out a number of branch heads during recurring warm days when the temperature does not become sufficiently low to kill the plant itself. As already pointed out, the midge likewise will emerge irregularly during the winter months, and as these heads present the opportunity, oviposition takes place. The normal larvæ are then formed and during

the winter it is no uncommon thing to find them within the glumes, but the writer has not found a single instance in which normal larvæ occurred in heads that had been formed during the summer and allowed to stand for a sufficiently long time to yield midges from all possible infestation; only occasional naked pupæ and a predominance of "cocooned larvæ" are contained in the latter.

These "cocooned larvæ" are formed in the seed during the entire breeding season of the midge. As early as June, in the latitude of San Antonio, Tex., these forms were found, and there seems to be no regularity in their habit of emerging. After all emergence has ceased from normal naked larvæ these forms develop into cocooned pupæ and emerge irregularly. Ofttimes a cocooned pupa is found upon a seed along with a normal naked larva. Just what controls the development of this form has not been discovered. Attempts to induce hibernation artificially by subjecting these to low temperatures and later placing them in a warm room have been unsuccessful.

RELATION OF JOHNSON GRASS TO THE MIDGE PROBLEM.

From what has been said previously in regard to the midge in relation to Johnson grass, it is a self-evident fact that this grass furnishes the key to the situation. Johnson grass allowed to remain over winter in and about sorghum fields carries the midge until spring, and being the first to head and bloom, gives the midge a good start, and by the time the sorghum is headed there is a large brood of midges from the grass ready to infest it. (See Pl. I, fig. 1.) Johnson grass is generally considered one of the greatest pests on the farm, and its function as a host for the sorghum midge serves as but another indictment against it. It is no uncommon sight to find sorghum fields from which the last crop has been harvested, with Johnson grass growing and heading in the fence corners (Pl. II, fig. 3) and even in the fields (Pl. II, fig. 2).

NATURAL ENEMIES.

PARASITES.

The midge in certain localities is abundantly parasitized by a small black hymenopterous parasite determined as *Aprostocetus diplosidis* Crawf. (figs. 29, 30) and by a smaller parasite determined by Mr. Crawford as *Tetrastichus* sp. (fig. 31). The latter is known to be both primary and secondary, but it is more likely to be primary in its relation to the midge. These latter parasites are reared from infested sorghum heads along with the predominant *Aprostocetus diplosidis*. Although the predominant parasite is very aggressive and parasitizes the midge very actively it does not become sufficiently numerous to materially check the midge until late in the

summer, when the second and third crops of sorghum are heading. These crops are found to mature upward of 90 per cent of sound seed, while the earlier crops are a total failure. Late in summer emergence of these parasites and midges from infested heads is approximately in the proportion of 6 of the former to 1 of the latter.

Only one observation has been recorded as to the feeding habit of this parasite. On August 1, 1908, the writer observed the parasites clustering upon the leaves of the spined Amaranthus (*Amaranthus spinosus*), commonly known as "careless weed." Investigation revealed that these followed in the wake of some leaf-eating beetles which abraded the leaves, from the torn edges of which the juice oozed. This the parasites fed upon, following the leaf eaters as they changed

FIG. 29.—*Aprostocetus diplosidis:* Female. Greatly enlarged. (Original.)

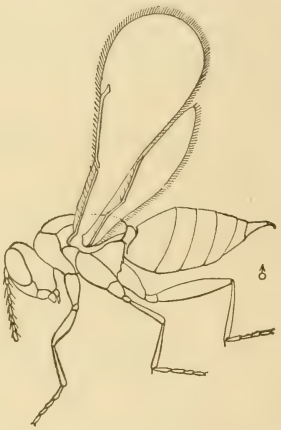

FIG. 30.—*Aprostocetus diplosidis:* Male. Greatly enlarged. (Original.)

their point of attack. These beetles were afterwards determined as *Disonycha collata* Fab. and *D. glabrata* Fab.

The distribution of *Aprostocetus diplosidis* is generally the same as that of the sorghum midge, although in some sections where the latter abounds the parasite is not found.[a]

The method of parasitism can be seen readily in the field. The parasite crawls slowly over the infested heads and then, apparently locating a larva, takes up a position upon the spikelet, the head toward the apex of the latter, and arching the abdomen drives the ovipositor through one of the glumes to the interior.

The species of *Tetrastichus* referred to, while not proved to be primary in conjunction with *Aprostocetus diplosidis*, is certainly primary upon the midge in some instances. During the early part of the season, when only Johnson grass is available as a host for the midge

[a] Fayetteville, Ark., and Neodesha, Kans., have not been recorded as sections abounding in the parasite, although the sorghum midge occurs quite abundantly.

FIG. 1.—EARLY JOHNSON GRASS HEADING AND BLOOMING ON WET BANKS OF SEWAGE CANAL, SAN ANTONIO, TEX. (ORIGINAL.)

FIG. 2.—RUBBISH LEFT BY REMOVAL OF SORGHUM SHOCKS IN A FIELD NEAR SAN ANTONIO, TEX. (ORIGINAL.)

and the predominant parasite is not found, these parasites may be seen actively ovipositing through the outer glume of the sorghum seed in precisely the same manner as has been described with reference to *Aprostocetus diplosidis*. At the same time the writer has reared this parasite from *Setaria glauca* infested by another species of midge.

The pupæ of *Aprostocetus diplosidis* and *Tetrastichus* sp. are found occupying the same position within the spikelets as is taken by the pupæ of the sorghum midge, viz, directly against the ovary within the delicate palet, the head directed toward the apex of the seed. These pupæ are not enveloped in the larval skin of the midge, but are naked. While microscopic examinations of sectioned midge larvæ have not been made for the purpose of studying the development of these parasites, it is evident that these parasites oviposit within midge larvæ in all stages of development. Examination of seed observed to have been visited by parasites has revealed, in some instances, newly hatched larvæ, while in other cases half-grown or even full-grown larvæ were present.

FIG. 31.—*Tetrastichus* sp.: Female. Greatly enlarged. (Original.)

PREDACEOUS ENEMIES.

By far the most important predaceous enemy of the midge is the Argentine ant (*Iridomyrmex humilis* Mayr) occurring in Louisiana. These ants swarm over the sorghum stalks and heads in the fields and whenever they find midge pupæ projecting from the apex of the glumes they seize the latter in their mandibles and carry them off to their nests.

The fly *Psilopodinus flaviceps* Aldrich has been observed by the writer to prey upon the adults of the midge. These flies rest upon a sorghum blade conveniently near a head and dart out frequently, seizing an adult and devouring it immediately.

On July 15 the writer saw a hummingbird (probably *Trochilus alexandri*, according to Prof. F. E. L. Beal, of the Bureau of Biological Survey) hovering about the heads of sorghum, which were at the time swarming with midges. To all appearances it was feeding upon the sorghum midge. Professor Beal states that small spiders and minute insects are often found in the stomachs of hummingbirds.

REMEDIAL MEASURES.

DESTRUCTION OF JOHNSON GRASS.

The destruction of Johnson grass is one of the most vital factors in midge control. The mere cutting of this grass is not sufficient. It should be burned over wherever discovered, and such areas plowed in the spring to prevent an early crop of heads.

The practice of allowing Johnson grass to grow within and around areas planted to sorghum is sure to furnish ideal conditions for early and late infestation by the midge, while the small isolated patches of the grass in fence corners will carry the species over winter in the seed.

CLEAN HARVESTING.

Careless methods of harvesting the sorghum crop are largely responsible for damage by the midge. It has been pointed out that stalks allowed to stand in the harvested fields will continue to send out until late in the winter branching heads, which furnish breeding possibilities and, later, hibernating material. Again, when the crop is harvested, the stubble should be burned over after all loose heads have been collected and burned. Such heads allowed to lie upon the harvested fields over winter harbor the hibernating midges until the following spring. In many sections it is customary to stack the harvested sorghum stalks in the field for winter use as a dry fodder. This practice, as can be readily understood, furnishes unlimited possibilities for the midge to successfully pass the winter. (See Pl. I, fig. 2, and Pl. II, fig. 1.

DESTROYING HEADS OF FIRST CROP.

Inasmuch as the early crop of seed is practically destroyed by the midge and the second crop matures a very large percentage of sound seed, it is possible that the practice of destroying the first crop of seed and retaining the last crop will yield better results and at the same time eliminate a very great percentage of midges. The fumigation of thrashed seed and storing it in tight receptacles would possibly prove effective in reducing the number of emerging adults from seed stored for planting purposes.

BAGGING HEADS.

When a small crop of seed is desired for planting purposes it will be found practical to protect the heads from the midge by bagging as illustrated in figure 22. This should be done before the heads have broken through the protecting sheath, i. e., before the stage illustrated in figure 27, *a*, and the bags allowed to remain until the seed are mature and hardened. Of course this method is not practical of application on a large scale, but when a small crop is desired it will be found to suit the purpose admirably.

FIG. 1.—HARVESTED FIELD OF SORGHUM NEAR SAN ANTONIO, TEX., SHOWING SCATTERED HEADS. (ORIGINAL.)

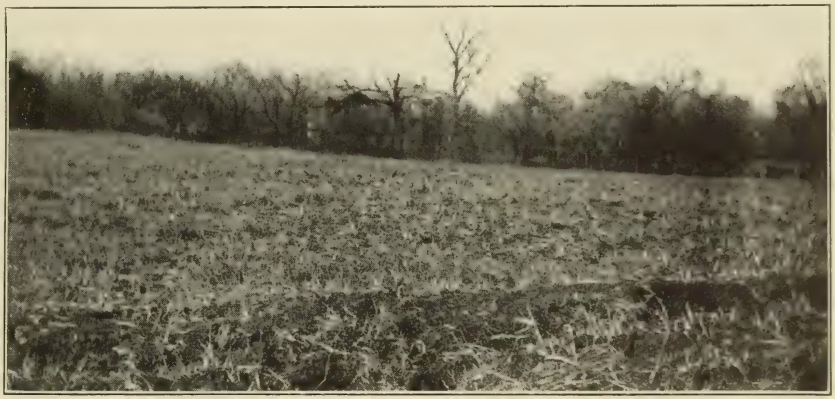

FIG. 2.—HARVESTED FIELD OF SORGHUM NEAR SAN ANTONIO, TEX., IN WHICH THE SORGHUM MIDGE IS HIBERNATING. (ORIGINAL.)

FIG. 3.—FENCE LINE BORDERING A SORGHUM FIELD NEAR SAN ANTONIO, TEX., ALLOWED TO GROW UP IN JOHNSON GRASS. (ORIGINAL.)

PAPERS ON CEREAL AND FORAGE INSECTS.

THE NEW MEXICO RANGE CATERPILLAR.

(*Hemileuca oliviæ* Ckll.)

By C. N. Ainslie,
Agent and Expert.

INTRODUCTION.

During the month of August, 1908, information reached the United States Department of Agriculture at Washington that a destructive invasion of certain sections of the cattle range in northeastern New Mexico by an immense army of caterpillars had been in progress for several years, and that the damage seemed to be steadily increasing with each successive year.

The facts, as stated, were so specific and the source so trustworthy that the matter was deemed worthy of immediate attention. Accordingly the writer, who was then busy with other insect problems in southern New Mexico, was instructed to proceed as soon as practicable to the infested territory in the vicinity of Springer, N. Mex., make a thorough study of existing conditions, and report on the life history of the pest and the feasibility of methods of extermination or control.

The following pages give the results of this investigation which was begun in October, 1908, and was continued throughout the greater part of the summer of 1909.

The writer is under great obligations to Prof. F. M. Webster, to whose advice and cooperation many of the results of the study are due; to Dr. Harrison G. Dyar, who has kindly described the various larval stages and the adults and has supervised the drawings of the larval and adult forms, besides contributing the entire section relating to "the specific identity of the insect concerned;" to Messrs. Frank and Charles Springer and to Mr. Henry Springer for the many kindly courtesies that have made this investigation possible; to Mr. H. M. Letts, of Koehler, N. Mex., for valuable assistance; and to others both in New Mexico and in Washington who have in various ways aided in this study. The writer is responsible for the statements concerning the life history of the insect herein recorded, all of which are original with the present investigation and are believed by him to have been correctly interpreted and recorded.

HISTORY AND EXTENT OF THE OUTBREAK IN NEW MEXICO.

As has just been stated, the first information that reached the United States Department of Agriculture at Washington concerning the alarming increase of Hemileuca caterpillars in New Mexico came in August, 1908. A letter from Mr. Frank Springer, one of the owners of the large Springer ranch that lies between the villages of Springer and Cimarron in Colfax County, was forwarded to Washington by Prof. T. D. A. Cockerell, to whom it was addressed. This letter contained a brief account of the damage then being done to range pastures in the vicinity of Springer by legions of caterpillars that had apparently been increasing in numbers for several years. Mr. Springer stated his belief that, unless checked in some way, these pests threatened to become a serious menace to the cattle-raising industry of northern New Mexico.

The interest aroused by this presentation of somewhat startling facts resulted in a careful study of the depredating species covering the adult period of the insect in 1908 and the entire active life period of 1909.

The history of the range caterpillar prior to the outbreak of 1908 is exceedingly vague, and the information obtained from ranchmen and others is very unreliable, probably owing to the fact that they have not been able to distinguish clearly between these caterpillars and those of other species. A notable illustration was offered during the year 1909. There was a severe outbreak of the wheat-head army worm (*Heliophila albilinea* Hübn.) in northern New Mexico, which took place simultaneously with the occurrence of the Hemileuca larvæ, while in many cases reports current through the country attributed all of the ravages to the range caterpillar. In view of what we have learned since taking up the investigation of the range caterpillar, it would seem that the species might have had its origin in the country east of and adjacent to the Rocky Mountains in northeastern New Mexico. The information relative to the occurrence and food habits of closely related species is as yet too meager to throw much light upon this problem. It is possible that there have been previous outbreaks of this particular species of Hemileuca, but if so the evidence is too meager and obscure to permit of any definite statement to that effect. The extremely limited extent to which the range caterpillar is affected by natural enemies is of itself somewhat puzzling and would rather indicate that if there had been previous outbreaks these were overcome, if at all, very slowly, by natural enemies. If all of these questions were capable of prompt solution, we might have a basis for estimating the probable extent to which the pest will spread over adjoining country; with our present knowledge, however, it will require at least another season to determine whether the species will retain its foothold in adjacent States to the north and

FIG. 1.—MESA NEAR KOEHLER, N. MEX., WITH CHARACTERISTIC VEGETATION—GRAMA GRASS, ARTEMISIA FRIGIDA, AND GUTIERREZIA SP. (ORIGINAL.)

FIG. 2.—PASTURE ON THE C. S. RANCH NEARLY DESTROYED BY NEW MEXICO RANGE CATERPILLAR. VEGETATION MAINLY GRAMA GRASS. (ORIGINAL.)

FIG. 3.—EGG MASSES OF THE NEW MEXICO RANGE CATERPILLAR (HEMILEUCA OLIVIÆ) ON A SINGLE PLANT OF RANGE GRASS; MALE MOTH IN RESTING POSITION. (ORIGINAL.)

east and continue to spread in these directions, or whether, owing to the high altitude and consequent atmospheric and meteorological conditions, it will be restricted to this particular section of the country.

The character of the country covered by the present outbreak should be mentioned here. Northeastern New Mexico consists mainly of a high plateau 6,000 to 7,000 feet above sea level, interspersed with mountainous masses that show evidence of volcanic action in some remote time. The entire region—plains, valleys, and even the "high mesas" 8,000 feet in altitude—is covered with a more or less complete clothing of nutritious grasses (Plate III, fig. 1). Little else will grow here. The systematic overstocking of the range in years gone by has, however, partly eliminated these grasses and allowed many worthless weeds like the sheepweed (*Gutierrezia* sp.) and the Russian thistle (*Salsola tragus*) to dominate large areas, to the detriment of the live-stock industry. The native grasses, such as the grama (blue and black) and Agropyron, seldom perish entirely from overstocking, but often afford only limited pasturage. Since the range caterpillar has taken possession of this entire region, feeding mainly on grama and buffalo grasses, the carrying capacity of the range has been much reduced, and in places utterly ruined. Not only has the grass been eaten to the very roots for miles at a stretch by these "range worms" (Plate III, fig. 2), but the uneaten grass in the infested territory is not relished by stock on account of the trail of silk left everywhere by the caterpillars, especially during the molting season.

The first authentic history of the genus Hemileuca in New Mexico begins about five or six years ago. In the year 1904 or 1905 a vast horde of caterpillars appeared in destructive numbers in the vicinity of Springer Lake, New Mexico, an irrigation reservoir a few miles from Springer, a station on the Santa Fe Railway, 50 miles south of the Colorado line. That section appears to have been the starting point of the present outbreak, and from there it has spread north and east and south, being checked on the west only by the foothills of the Taos Mountain range.

Whether or not this locality is the original home of this species, the pest has become most thoroughly established everywhere on the great rolling stretches of grazing land where it is now found. Even the weeds of the region, mostly adventitious, combine with the native grasses to make existence possible for the pests by affording shelter from the heat of the midday sun, support for molting, and, later, for pupation. Indeed it seems doubtful if this species could easily survive under the conditions that prevailed before the introduction of weeds, at least on the level plains.

But the Hemileuca is by no means confined to the broad, low-lying mesas. In August, 1909, a large colony of full-grown larvæ was discovered in a natural grama-grass meadow on the summit of one of

the foothill spurs near Koehler, N. Mex., several hundred feet above the level of the great plain below. Larvæ were also found for several miles up Crow Creek Canyon near Koehler, while in October of the same year large numbers of eggs were found in this same canyon, much farther back than the larvæ were observed during the summer previous.

It probably often happens, in the way of chance distribution, that egg-bearing females are forced to earth during their long flights, and oviposit where they fall, thus planting their eggs in locations which they would not normally reach or select. It is not at all improbable that the moths will eventually follow through or fly over the mountain ranges west of their breeding place and reach the vast grazing region of northwestern New Mexico and northern Arizona, even if they do not now occur there in limited numbers.

The area at present infested is not well defined, nor is it possible to ascertain its boundaries. It is known to extend from just north of Las Vegas, N. Mex., on the south, to Las Animas, Colo., on the north, and from Cimarron and Koehler, N. Mex., on the west, to points well within the Texas "Panhandle" on the east. Roughly speaking, an area 200 miles from north to south by 150 miles from east to west—30,000 square miles—is infested very unevenly as yet, but with the insect more or less prevalent everywhere.

OCCURRENCE OF THE MOTHS OUTSIDE OF NEW MEXICO.

On October 29, 1909, multitudes of Hemileuca moths, many of them very fresh and unworn, were flying about the electric lights at Trinidad, Colo., 148 males having been counted at two street lights 90 paces apart. This was the first intimation that the insects had crossed the high mountain range at Raton, N. Mex., and had invaded Colorado. On November 4 a number of these moths were taken at the lights at Las Animas, a town lying 100 miles northeast of Trinidad, Colo. How far beyond Las Animas they extend we have no means of knowing.

At Garden City, Kans., November 5, 1909, a number of moths, believed to be of this species, were seen about the electric lights, but it was a warm night, the moths were active, and no captures were made. Observant residents to whom specimens were shown declared that earlier in the season they had seen many moths of the species flying. There exists a doubt as to the presence of the species in Kansas, but it is known to be in Texas, Oklahoma, New Mexico, and Colorado. How far north the species will spread with its present start can only be conjectured, but by those who are familiar with the facts of the outbreak the situation is viewed with apprehension. It must be borne in mind, however, that only the moths have been

observed outside this limited area in New Mexico and the very similar adjacent borders of Oklahoma and Texas; whether or not the species can exist beyond this region is yet to be seen.

It seems probable that altitude may indirectly exert some influence on the distribution of this species of Hemileuca. In other words, below a certain altitude, under the peculiar climatic conditions that prevail in New Mexico and similar semiarid regions, the intense heat of the midday sun may prove fatal to the younger larvæ unless the character of the native vegetation affords the necessary shelter. Farther north, if the species follows the grama-grass range in that direction, as it seems to be doing at present, the chief danger to the insect may be the possibility of continued stormy or unfavorable weather during the egg-laying period in the fall.

THE SPECIFIC IDENTITY OF THE INSECT CONCERNED.

Specimens of this species were described by Professor Cockerell some twelve years ago as *Hemileuca sororia*, race *oliviæ*. The type, a male, came from Santa Fe, N. Mex., and is now in the United States National Museum. The species *sororia*, of which *oliviæ* was described as a race, was originally characterized by the late Henry Edwards from a single female from La Paz, Lower California. Nothing further is known of this form, except that *Hemileuca hualapai* Neumoegen, described from a single female from southern Arizona, has been referred to it as a variety. Nothing further is known of *hualapai* either, but in the light of the present situation it appears unlikely that these forms are races of one species, but rather separate species, and it has been thought best to here designate the species with which we are at present concerned as *Hemileuca oliviæ* Cockerell.

Beside the forms just cited, a number of closely allied species have been described from Mexico. Twelve species altogether are at present known which are closely allied to *oliviæ*, as follows:

Hemileuca rubridorsa Felder.

Felder's description is without definite locality; his figure represents a female. A male specimen, undoubtedly of this species, has been received from Mr. Roberto Müller, from Mexico City, which enables us to locate the species as an inhabitant of the Mexican plateau.

Hemileuca norba Druce.

Described from Amecameca, State of Morelos, Mexico, from the same general region as the foregoing. The type specimen, a male, is before us, but no additional material.

Hemileuca minette Dyar.

This form is probably from the vicinity of Mexico City, although the single type is without exact locality. The three species may possibly be but variations of one species, but from the present scanty material they seem distinct, and must be considered so until proven otherwise.

Hemileuca hualapai Neumoegen.

Known only by a single female from southwestern Arizona. In the absence of fresh material we have only the original description to go by, which indicates that the species is not the same as *oliviæ*. The costa is stated to be bright yellow, which is not the case in the female *oliviæ*, although there is considerable ochreous shading in some specimens. The whole insect is described as being very pale and rose colored. While it is impossible to decide the exact specific standing of the form from the description of one female specimen, it seems best at present to consider it a distinct species.

Hemileuca mania Druce.

Described from Orizaba, Mexico. We have specimens from Mr. Müller, collected in Motzorongo, both localities in the State of Vera Cruz in the hot, moist country. The females appear very similar to the description of *hualapai*, being pale rosy with a bright yellow costa.

Hemileuca lares Druce.

This was described from Durango City, which is on the high tableland at the foot of the Sierra Madre. No specimens are before us, the species being known to us by Druce's figure.

Hemileuca numa Druce.

This was described from Mexico City. We have specimens from there in the Schaus collection and others sent by Mr. Müller.

Hemileuca nitria Druce.

This species is evidently very close to *numa*. We have no specimens, and the original type is without definite locality. Probably it came from somewhere on the Mexican tableland. It may even be not specifically distinct from *numa*.

Hemileuca oliviæ Cockerell.

The present species falls here in general relationship, being apparently most nearly allied to the three following.

Hemileuca sororia Hy. Edwards.

As stated above, known only from the original type specimen from La Paz, Lower California.

Hemileuca marillia Dyar.

Described from Tehuacan, State of Puebla, Mexico, on the southern end of the Mexican plateau. Closely allied to the following.

Hemileuca lex Druce.

Described from a single male from Durango City, from the western edge of the central part of the Mexican plateau.

It will be seen that, of the 12 nominal species above, 8 are from the Mexican plateau (including 2 without exact localities), 6 from the lower and best known part of that region in the vicinity of Mexico City, and 2 from the central portion in the State of Durango. Of the outlying 4 forms, 1 is known from the peninsula of Lower California, 1 from southwestern Arizona, and 2 from New Mexico, while but a single species occurs outside of the high dry prairie region, namely *H. mania* Druce, from the State of Vera Cruz, which is

geographically close to the main center of distribution. In the center of distribution, the Mexican plateau, several species may occur in the same region; but whether they are actually associated or not is not known; in the outlying portions of this area the species occur singly.

Probably all these species are grass-feeders in the larval state and are derived from a common ancestor with this habit which was originally developed from the Mexican plateau, where prairie conditions prevail.

FIG. 32.—Egg mass of *Hemileuca oliviæ* on weed stem. Enlarged. (Original.)

DESCRIPTION.

Below are given the technical descriptions of the egg, larval stages, pupa, and adults:

THE EGG.

Egg (fig. 32) broadly oval, upper end slightly the larger. A large saucer-shaped depression on two opposite sides gives a somewhat quadrate appearance when viewed from above. Apex flattened, with a small circular central depression that includes the micropyle.

The entire egg is covered with a dense, homogeneous coating of opaque, impervious material that is quite adhesive when fresh. By stripping off this outside pellicle the true shell is disclosed, delicate and membranous, finely and irregularly reticulate.

The egg is filled with a finely granular, dark reddish brown fluid that retains its peculiar color throughout the entire egg period, but disappears gradually as the embryo develops, becoming less noticeable during the later stages of incubation.

Size, exceedingly variable, with an average measurement of 1.5 by 1.8 mm.

THE LARVAL STAGES.

Stage I (fig. 33).—Head rounded, shining black, the setæ rather coarse, whitish; width about 0.75 mm. Body subcylindrical, uniform dark brown; the spines black, equal, with single long whitish primary setæ; on the abdominal segments tubercle *i* is at the summit of a spine, *ii* from the skin without spine, *iii* from a spine, *iv* and *v* from a single spine; leg plate with two small setæ; on joint 12 a single forked dorsal spine bearing tubercles *i* of the two sides, *ii* from the skin as on the other

FIG. 33.—The New Mexico range caterpillar: Larva, first stage. Highly magnified. (Original.)

segments; on joint 13 a single forked dorsal spine posteriorly, single subdorsal anterior, single lateral, none from the skin. On the mesothorax and metathorax tubercles *ia* and *ib* on a single forked spine, *iia* and *iib* on another, *iii* and *v* on single spines. On the prothorax two forked spines on the anterior margin of cervical shields and one seta from the skin posteriorly; a forked spine bearing two setæ

represents the prespiracular tubercle; a single seta on a spine subventrally. Anal plate black, with setæ but no spines. There are no secondary hairs and no markings.

Stage II (fig. 34).—Head rounded, black, with white setæ; width about 1.2 mm. Body subcylindrical, uniform dark brown, with a number of small whitish secondary dots from which arise small pale hairs. Thoracic feet moderate, the abdominal ones equal, tapered, with thick bases, the anal pair with large triangular plates. Spines

FIG. 34.—The New Mexico range caterpillar: Larva, second stage. Greatly enlarged. (Original.)

rather short, all about the same length, situated in the positions of the spines of the first stage, each with several short branches or notches bearing fine setæ; the subdorsal spines on joints 3 and 4 have several of these branches modified into quills with short sharp points, which are the urticating spines. They are developed in this stage only on the subdorsal spines of joints 3 and 4 (mesothorax and metathorax), and only three on each spine.

Stage III (fig. 35).—Head rounded, higher than wide, smooth, shining reddish-black; setæ coarse, white, a few secondary ones near the ocelli; width about 1.8 mm.

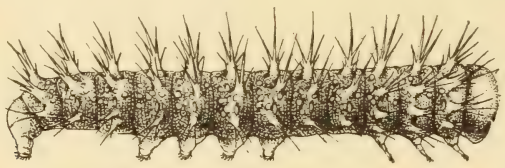

FIG. 35.—The New Mexico range caterpillar: Larva, third stage. Greatly enlarged. (Original.)

Body subcylindrical, uniform; feet equal, the anal pair with large triangular plates, all the leg-plates setose. Skin brown, with a number of secondary pale-yellow granules bearing whitish hairs. A faint yellowish subdorsal line in which the granules are denser than elsewhere. Subdorsal spines of joints 3 and 4 short and dense, the others slender with sparse branches. The sparse branches bear setæ, the short dense ones have short pointed tips, and are the urticating spines. Spines and spinules mostly black.

Stage IV (fig. 36).—Head rounded, higher than wide, flat in front, clypeus small; smooth, shining, black or blackish red. Hairs coarse, white, a number of secondary

FIG. 36.—The New Mexico range caterpillar: Larva, fourth stage. Much enlarged. (Original.)

ones about the region of the ocelli; mouth-parts and antennæ black. Width about 3.5 mm. Body cylindrical, equal, normal, the feet equal, the crochets of the abdominal feet long, in a line. Yellowish, shaded with blackish, the secondary hairs arising from large, yellow, flattened granules, so numerous as to cause the general yellow appearance; a faint, geminate, dorsal, more distinct subdorsal, narrow lateral, and

subventral lines, produced largely by an increased number of granules in those regions; secondary hairs small, white. Thoracic feet and anal shield black, the outer sides of the abdominal feet dusky. Spines of the subdorsal row on joints 2 to 12 short, with dense black spinules, the lateral and subventral rows longer, slender, with scattered pale spinules. Spiracles white, ringed with black.

Stage V (fig. 37).—Head rounded, higher than wide, flat in front, clypeus small; smooth, shining dark red, or black. Hairs coarse, white, intermixed with shorter but similar secondary ones even to the vertex; mouth parts and antennæ black. Width about 5 mm. Body cylindrical, uniform, normal, the feet equal, the crochets

FIG. 37.—The New Mexico range caterpillar: Larva, fifth stage. About natural size. (Original.)

of the abdominal feet dense, in a single line. Ground color yellow, grayish yellow, or black, densely covered with large, flattened, secondary yellow granules, so that the general effect is yellow, subdorsal and lateral lines of granules indistinctly relieved. Thoracic feet and anal plate black; abdominal feet darkly shaded. Secondary hairs short, pale. Subdorsal spines on joints 3 to 12 short, single on joints 12 and 13, no spines on the anal plate; lateral row of joints 2 to 13 and subventral row on joints 2 to 12 besides lower subventral row on joints 2, 3, 4, and 11 longer, slender, with more remote spinules. Spinules of the subdorsal row black, with central pale band, the other spinules largely pale. Spiracles white, with a black ring.

THE PUPA.

Pupa (fig. 38) rounded, elliptical, obtected, with three movable incisures. The female pupa is thickest through the middle and tapers roundedly both ways, only a little more obtusely so on the anterior end. The male pupa is thickest through the thoracic region and tapers decidedly posteriorly, being bluntly rounded in front. The antennal cases are very large in both sexes, those of the female only a little smaller than those of the male. Cremaster a blunt, corrugated prominence bearing a group of long spines with thickened, recurved or partly curled tips, which become firmly entangled in the web of the cocoon.

FIG. 38.—The New Mexico range caterpillar: Pupa, lateral view. Enlarged. (Original.)

THE ADULT OR MOTH.

Male (figs. 39 and 40).—Antennæ with long pectinations, a pair on each segment arising well toward the dorsal aspect, strongly curved, the tips directed downward; a row of single, short, overlapping, ventral serrations. Wings rather short and broad. Head and thorax covered with dense, long hair, gray or clay colored, intermixed with gray and underlaid by dull crimson. Abdomen red, varying from orange-red to red-brown, darker, more crimson at base, occasionally intermixed with black. Wings generally light clay color, almost whitish, the fore wing crossed by two broad, shaded and diffused, paler and more whitish bands; discal mark narrow, devoid of scales, more or less stained with ocherous and often surrounded by a darker ring. The color of the fore wing varies considerably and may be even of a rather dark gray, in which case the transverse bands are more strongly relieved. Hind wing generally without markings, though

occasionally there are traces of a dusky mesial band. The wings are not tinted with rose except sometimes at the base of the fore wing. Beneath, the wings are

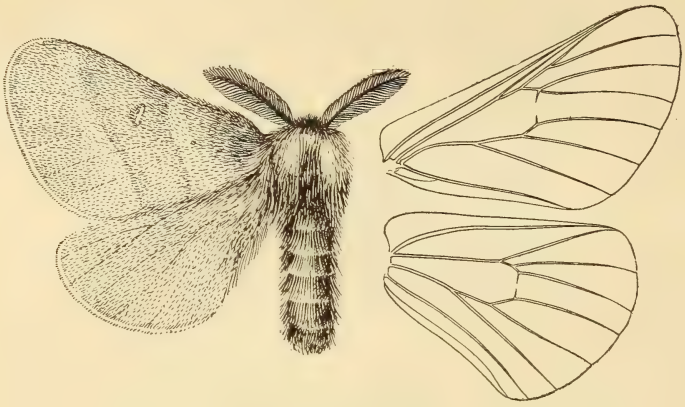

FIG. 39.—The New Mexico range caterpillar: Male moth and wing venation. Enlarged, venation more enlarged. (Original.)

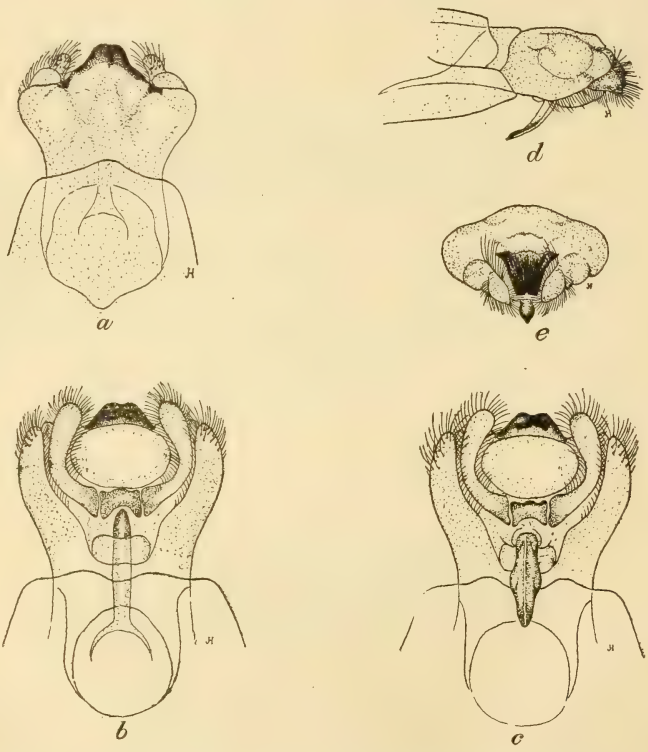

FIG. 40.—*Hemileuca oliviæ:* Male genitalia; *a*, dorsal aspect; *b*, ventral aspect, penis retracted; *c*, ventral aspect, penis extended; *d*, lateral aspect; *e*, terminal aspect. (Original.)

without markings, the costa of the fore wing and the veins stained with bright ocher, the cell shaded with a rosy tint, the outer area somewhat shaded with

brownish; hind wing immaculate. Thorax and abdomen beneath clothed with long hair which varies in color from gray to blackish gray, more or less tinted with ocherous. Legs bright dark ocherous. Expanse of wings, 45 to 55 mm.

Female (figs. 41, 42).—Antennæ short, thickened, each segment with a short serration on each side, the ventral line slightly carinate. Thorax as in the male. Abdomen of a duller red than in the male, less densely hairy, the yellow integument showing at the incisures. Wings darker than in the male, clayey brown or grayish brown, rarely with rosy tint throughout, the lines pale, diffused, narrower than in

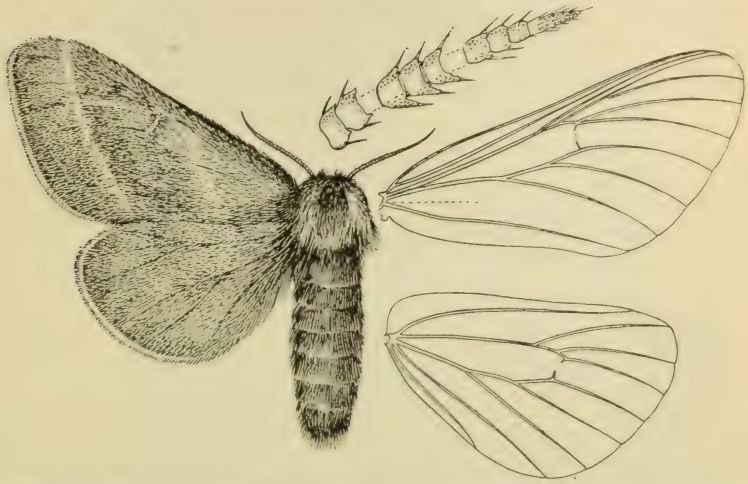

FIG. 41.—The New Mexico range caterpillar: Female moth, wing venation, and details of antennæ. Enlarged, venation more enlarged, antennal joints greatly enlarged. (Original.)

the male; discal mark the same. Hind wing as dark or somewhat darker than fore wing, uniform brownish, generally rosy tinted, the fringe of both wings pale. The veins of both wings have a slight tendency to be lined with ocherous and the costa is more or less distinctly washed with that color, though not with a distinct ocherous stripe. Beneath, the body is blackish gray, the segments banded with whitish. Wings uniformly colored, the cell of fore wing rosy shaded, the costæ and veins of both wings washed with ocherous. Expanse, 55 to 65 mm.

LIFE HISTORY AND HABITS.

THE EGGS.

OVIPOSITION.

The usual time for depositing the eggs is in the early part of the day, with the climax about 9 or 10 o'clock in the forenoon. The female has mated during the evening previous, and as soon as the morning air grows warm she selects a stem of weed or grass, of sufficient diameter and free from irregularities if possible. Taking her position on this, within an inch or two of the ground, usually, she first places a ring of eggs about the stem, attaching them both to each other and to the stem. On this for a foundation she proceeds to deposit her supply of eggs in the form of a cylinder (fig. 32; Plate III, fig. 3), placing them entirely by the delicate sense of touch resid-

ing in the tip of the ovipositor. Every 40, 50, or 60 seconds the pendent abdomen of the moth is slowly brought forward and upward, and the extensile tip of the ovipositor explores the ins and outs of the upper edge of the egg-mass until the proper notch is discovered, and is held there for a few seconds while the next egg is forced down the oviduct into place. Then the abdomen is carefully lowered and the insect remains motionless for more than half a minute while the egg dries and becomes fixed. The operation of placing the entire supply of eggs occupies normally or under favorable circumstances nearly two hours. The length of time required depends almost wholly on the weather, for moths have been observed more than once during a driving snowstorm, nearly buried in snow, late in the afternoon, painfully and with the utmost difficulty striving to complete the morning's task of providing for posterity before the increasing cold should render it hopelessly impossible.

FIG. 42.—The New Mexico range caterpillar: Female moth in characteristic resting attitude. Enlarged. (Original.)

As the eggs pass from the oviduct they are coated with a brown viscid substance that serves not only to attach them firmly to each other and to the central stem, but may also be necessary in protecting them from the changes of the weather during the nine months that they remain exposed out of doors. This brown coating dries in a few seconds to a brownish pink with a pearly luster that gradually fades under the long-continued action of the elements. The eggs are so firmly cemented by this substance that the cylinder easily keeps its form after the stem around which it has been built is withdrawn.

The number of eggs deposited by a female varies exceedingly, and the conclusion has been reached, after repeated observations, that the number depends much upon the favorable or unfavorable food conditions under which the larvæ live. Moths produced from caterpillars reared on rank grass contain twice or three times the number of eggs of those from starved larvæ. A dissection of fourteen chrysalids and freshly emerged females gave the following egg counts: 60, 97, 76, 118, 112, 97, 97, 90, 177, 162, 122, 113, 129, 140.

The females evidently oviposit near where they emerge and mate, with the exception of the large contingent that emigrates unmated. The male frequently spends the day where mating took place and remains motionless long after the female has placed her eggs and flown away. (See Plate IV, fig. 1.)

FIG. 1.—MALE MOTHS OF THE NEW MEXICO RANGE CATERPILLAR RESTING DURING THE DAY ON STEM OF WILD SUNFLOWER. (ORIGINAL.)

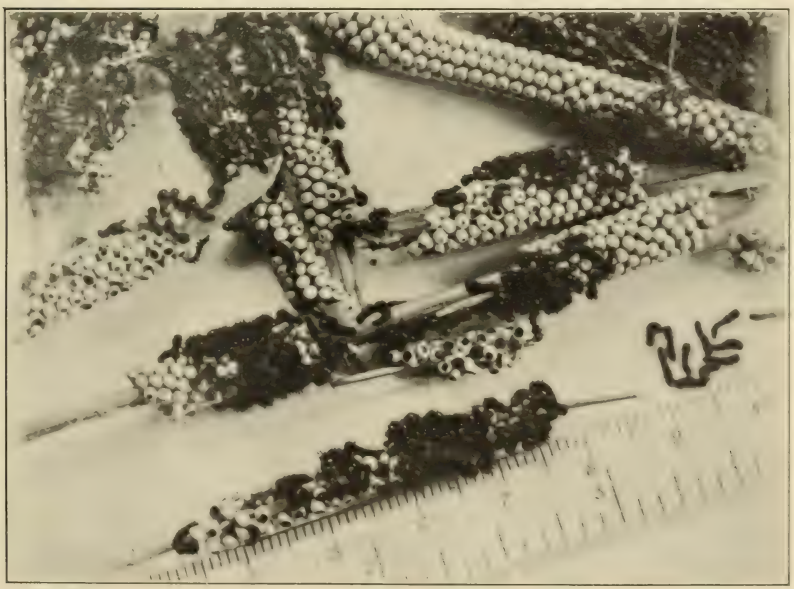

FIG. 2.—HATCHING OF THE EGGS OF THE NEW MEXICO RANGE CATERPILLAR. SIZE OF LARVÆ INDICATED BY METRIC RULE BENEATH. (ORIGINAL.)

LOCATION OF THE EGG-MASSES.

The egg-masses, the characteristic appearance of which is well shown in figure 32, and in Plate III, figure 3, are exceedingly numerous on many parts of the range. They are frequently placed in close proximity to each other, and as many as six and eight clusters have been counted on the stems of a single small sod of grass. Numerous instances have been observed where a single stem has furnished support for three or four egg-masses, each female as she arrives continuing the cylinder previously begun, until the aggregate length of the masses is sometimes 2 and even 3 inches.

It is a curious fact that few of the eggs are placed upon the food plants of the young caterpillars, but they are placed upon any plant that affords the necessary support for the egg cylinder, regardless of the needs of the larvæ.

HATCHING.

(Plate IV, fig. 2.)

All the eggs in a single cluster are opened by the larvæ within at about the same time. The first sign of internal activity is a very small hole, like a minute pin prick, in the vicinity of the micropyle. This opening is made by a thrust of the mandible from within and is enlarged very deliberately, the operation often requiring two or three days. The dense structure of the shell offers much resistance to the tiny jaws, so that a passage large enough for exit is bitten through with difficulty. An entire day will often pass without any perceptible gain in the opening, but eventually it is completed, for very few larvæ die in the shell.

That the thick shell of the egg is highly protective for the unhatched larvæ is shown by the fact that clusters of eggs dipped in alcohol, as well as others kept for several days in fresh cyanide bottles, all hatched, having evidently been uninjured by this drastic treatment.

The imprisoned larvæ seem very timid and will rarely make a move either to enlarge the opening or to escape from the egg while under observation.

When the aperture in the egg has been enlarged until it corresponds nearly to the size of the face plate, which is the only rigid and unelastic part of the larva, the head is withdrawn from its position before the opening, the caudal end is thrust out, and little by little the tiny prisoner makes its escape. Not infrequently the face plate fits the doorway so snugly that a protracted struggle is necessary before the head can be extricated.

Occasionally, but not often, the head is thrust from the shell at the beginning of the exit and the body quickly follows.

The long hairy tips of the thoracic tubercles fall forward over the face when the body emerges first, but become erect as soon as the moisture dries away.

The date of larval emergence seems to vary widely with the season. No definite information is obtainable prior to 1908, but during that year the first larvæ were noticed about the middle of June. It is said that in 1907 they appeared not far from July 1. In 1909 they began to emerge about May 20, and continued to appear until after July 1. The date of oviposition may govern the time of hatching, but the character of the season is without doubt a more potent factor in this matter.

Dissection of the eggs at various times after oviposition has shown that the embryo forms within a few weeks, and that months before they emerge the larvæ are lying within the shells, fully formed and ready to appear at any time when external conditions will permit.

When removed from their New Mexican environment the eggs hatch much before the normal time. A large number that were gathered late in October, 1908, and taken to Washington, D. C., began to hatch by December 22, at least five months before similar eggs hatched in New Mexico in the following spring.

A handful of egg clusters gathered from the mesa in Colfax County, N. Mex., March 7, 1909, and taken to the vicinity of Las Cruces, N. Mex., 400 miles farther south and 2,500 feet lower, began to hatch on April 10, though kept in a cool room.

The excess of moisture that prevails in Washington might be supposed to account for the premature appearance of the larvæ in that city, but the atmosphere at Las Cruces is probably as lacking in moisture as is that in northern New Mexico. In both these instances the change of altitude may have had some importance as a factor in hastening the larval emergence. Several clusters of eggs were under observation and the young larvæ appeared to have some trouble in hatching, but when the writer moistened the egg with warm water the larvæ in the shells became much more active and seemed to be able to gnaw their way through the shell without difficulty. This shows the probable effect of warm showers on the range in facilitating the hatching and perhaps preventing many fatalities among the unhatched larvæ.

The interior of the egg at oviposition is filled with a thin reddish-brown fluid. As the embryo develops this fluid thickens and becomes less noticeable until it has nearly disappeared, when the larva emerges.

THE LARVÆ.

HABITS OF THE YOUNG LARVÆ.

The young larvæ, when they emerge from the egg, are a dull brick-red. This color changes in a few hours, becoming very dark, nearly black. They are quite sluggish at first, but are somewhat positively phototropic and show a tendency to colonize on the side of the cylindrical egg cluster that is most exposed to the light.

Their emergence is gradual and usually a day or two is required for all the inmates of a single cluster to appear. The newly emerged larvæ are conspicuous red individuals among a mass of darkened forms. As their numbers increase they give to the immediate landscape a peculiar appearance, for they show as little black balls here and there on grass sods and weed stems. Their favorite exercise is to raise the front half of the body free and wave it to and fro a number of times, somewhat rapidly.

When kept in confinement they often spin a carpet of silk over the surface of the eggshells, but this is seldom seen out of doors.

For several days after hatching the young caterpillars remain massed about the remains of the eggs (Pl. IV, fig. 2), feeding occasionally on the empty shells. They are continually in slight motion, their black, shiny bodies glistening in the sunlight as they constantly change places. The group gradually breaks up as the earlier-hatched ones string away from the parent colony in processions of 20, 30, or 40. These move in single, double, and triple file, the inequalities of the ground compelling constant changes in formation.

This processional habit, better known and more exhaustively studied in the well-known and widely distributed species *Hemileuca maia* Dru., is very amusing and is persisted in until the third larval instar, after which the individuals appear much annoyed at the near approach of a neighbor, large or small. The processions, as they move about on the mesa, seldom go in straight lines, but are guided apparently by the caprice of the one that happens to be in the lead. There is no rest for the leader, for if it happens to pause for a moment, the movement from the rear compels progress, and off the line goes again, toiling across the surface. Often the leader ascends a grass blade, reaching the top, swings about, catches the nearest blade if within reach, if not, goes down the other side while the procession is still passing up. These parties often subdivide, and if they come upon another lot during their rambles the two processions may coalesce. Removal of the temporary leader seems to produce no perceptible effect on their movements, and in no case does there seem to be any definite goal in sight. The column will often "ball up," remain in a black mass, sometimes an inch or more in diameter, on a

weed or grass stem, then gradually grow restless, get in motion again, and resume the line of march.

At rare intervals they pause long enough to eat a few mouthfuls of grass, but one may often watch these parades for hours and not see one of the young travelers stop for a single bite. Not infrequently larvæ of different ages will join the same procession. More or less silk is spun in the track of the moving line at times and this tenuous silken trail may aid in maintaining the continuity of the procession. If by any chance, as sometimes happens, half a dozen or more become separated from their companions, they eagerly join any procession they can find in their neighborhood. Indeed, during the first month of larval life the young are exceedingly gregarious and generally refuse food when placed alone.

On July 30, 1909, a single very much belated newly hatched larva was found on Bouteloua, and an effort was made to rear it. But, although furnished with ample food, its meals were brief and it was forever on the move, looking for company. It died August 9, "in the midst of plenty," apparently normal and healthy, but unable to find the companionship for which it had searched for ten long days.

During the nights, which are almost always very cool at this altitude, the young gather in a ball on some convenient stem and remain in masses, but are uneasy until the warmth of the morning starts them off for another day's "tramp."

HABITS OF THE OLDER LARVÆ.

The more mature larvæ are wasteful eaters, biting off and dropping many grass blades that they do not use. In the dry weather that prevails on many parts of the range, the blades of the Bouteloua and other food grasses are rolled up automatically into a tight cylinder to prevent too much evaporation. The larvæ usually bite off and drop the pointed tip, beginning to eat an inch or so below the apex of the blade, taking everything to the root. The grass is swallowed in rather coarse fragments and when voided is but little changed by digestion, much of the chlorophyl still remaining in the cells.

The jaws are powerful, for their food is leathery and nearly juiceless, requiring a strong bite. Several times while in captivity the larvæ have eaten quite a piece of heavy linen paper, their mandibles snipping through the firm edge of the sheet with an audible click.

As a rule the larvæ, especially in the earlier instars, are shy feeders, and the presence of a person in their vicinity is generally a signal to suspend all operations for the time being and to remain perfectly motionless. They sometimes display their annoyance at the intruder by a curious series of body motions, throwing themselves

from side to side sharply, supporting the weight on the rear legs, the head and thoracic legs being drawn beneath the curve of the arched body.

In the more mature instars, particularly the fifth, they lose some of their fear, and will sometimes eat quietly while being examined under a lens.

MOLTING.

When ready to molt the larva ascends a suitable stem, preferably the dead stem of a weed, and hangs head downward until the skin has been shed. Previous to suspension it usually, though not always, spins a light coating of silk upon the stem, and the hooklets of the posterior prop-feet are firmly attached to this web during the process of molting. The attitude assumed is like an inverted interrogation point, the head being drawn under the outcurved body.

If disturbed during the earlier stages of the operation the larva will manifest its annoyance by repeated quick jerks of the body from side to side, but no abuse however persistent will force it to abandon its hold on the silk when once established.

The character of the weather is an important factor at this critical period of the larval life, and a cloudy or stormy day or two will materially delay the molting. Larvæ have been seen to hang for several days waiting for favorable conditions, but molting usually takes place within an hour or two. The larva suspends itself in the early morning, or the previous evening, and before noon the skin is shed and the newly emerged caterpillar is drying in the sunshine.

The first noticeable step in the molting process is the inflation of the first thoracic segment, by which the head is thrust forward and the spines, that normally droop cephalad, stand stiffly erect. The segment is twice its usual length at this time.

After hanging motionless for some time, except for slight movements of the muscles, a regular rhythm is to be noticed, waves of motion that come slowly down the body to the head. As these pulsations continue, the thoracic region gradually inflates, and the larval skin separates from the body, until after fifteen or more waves, following each other at intervals of ten seconds, the paperlike skin opens along the side of the thorax and one gets the flash of fresh yellow rosettes of bristles emerging through the rent. The head is at once withdrawn, and in a few seconds the larva moves away, brave in its panoply of glittering yellow spines, which in the course of twenty-four hours turn dark. The face plate of the cast skin sometimes adheres and remains with the skin, but more often is pushed loose and falls to earth.

During the drying period, after emergence, the fresh larva has often been seen to bend its head back over the body and roll the two

halves of the body thus brought in contact, repeating this many times as if much pleasure was derived from the singular action.

LENGTH OF LARVAL STAGES.

Repeated attempts were made during the summer of 1909 to rear Hemileuca in confinement and secure data as to the length of the various instars, five in number. Without exception, these efforts proved failures, and for a number of reasons, some of which may be mentioned here.

As has been related elsewhere, the very young larvæ are almost constantly on the move, and any interference with their native liberty is resented. Within the limits of such cages as could be devised from scanty materials, these peripatetic caterpillars always became very much dissatisfied, and, after exploring all the interior repeatedly, would pay little or no attention to the food provided, grow listless, and ultimately starve to death.

The older forms were found to be extremely particular about their food, and they usually rejected such as was furnished them, even though this was the best that could be procured. When allowed to choose their own food under movable cages placed on the ground, they sulked, ate but little, and, where in a few cases they finally molted, the development was so abnormally slow that the record of the facts was worthless.

It was learned by observation that these caterpillars, in their native state, dislike exceedingly, and generally refuse to eat, grass over which their mates have left the usual fine trail of silk, although later this same trodden grass seems to become palatable. This reason for declining to feed was perhaps one of the main obstacles to success when attempting to rear these insects in confinement.

Observations made in the open appear to show that the first three instars are passed in rapid succession, each one lasting less than two weeks. The fourth instar is longer, while the fifth is indefinitely long, averaging at least four weeks. It is believed that these periods, as given, are approximately correct.

IRRITATING EFFECTS OF LARVAL SPINES.

The spines with which the larvæ are clothed are quite annoying and irritating, giving an effect, when touched, much like that produced by the urticating cells of the nettle. This irritation often lasts for an hour or two, especially when the thin skin of the arm or wrist is wounded. The spot puffs up almost at once, turns white, and when the swelling subsides, a brown point remains for days or weeks. Occasionally even the tough skin of the finger tips proves vulnerable, and a puncture there is generally very painful.

The larvæ seem to understand perfectly the value of the spines as a means of defense, for when they are grasped in the fingers they at once begin to twist their bodies with all their muscular force rolling themselves upon the fingers and hand to drive the spines into the flesh.

The larvæ often use these weapons upon each other, striking viciously at times when two large caterpillars come into unexpected and unwelcome contact. The results are not serious, but the efforts to wound appear to be in real earnest.

ABUNDANCE OF LARVÆ.

At different times during the summer, and at widely separate points, as far distant as 30 miles, counts were made of the caterpillars present on a measured square rod, in order to obtain some idea of the numbers of the pests. In each case the area was carefully measured and marked, and all the larvæ within the lines counted as they were gathered, so that the figures given are in every instance secured by an actual census. Efforts to estimate the numbers uniformly resulted in a guess much below the actual facts.

In a range pasture, many square miles in extent, near Koehler, N. Mex., a count made August 17, 1909, showed 181 nearly full-grown, active caterpillars feeding within the limits of a single square rod. This means the enormous total of 18,534,400 upon one square mile. While the numbers of the pests varied exceedingly, it is well within the truth to assert that many square miles in the neighborhood of Koehler were as densely infested as the square rod which was counted.

In the vicinity of Clayton, N. Mex., a town situated on the immense plains that extend far to the eastward across the Texas panhandle, the larvæ of the Hemileuca attracted so little attention that cattlemen who had observed them in former years declared over their signatures that none was present in 1909. Almost within a stone's throw of the residence portion of Clayton, on August 21, 1909, as many as 10 and 15 were counted to the square rod, or a million to a million and a half to the square mile.

It might be noted in passing that the failure to observe the existence of these caterpillars when present in only moderate abundance is not wholly due to lack of trained powers of observation, for the colors of soil and vegetation afford a certain amount of protection against discovery.

July 2, 1909, on two adjacent clumps of bunch grass (*Sporobolus airoides*) on the C. S. ranch, 17 miles from Springer, the caterpillars seemed numerous and were counted. On one clump 117 were feeding, on the other 128. These clumps were 20 to 24 inches across and stood 3 feet apart. Three instars were represented on this grass.

On August 24, 1909, 12 nearly full-grown caterpillars were counted upon a single square foot beside the road from Cimarron to Springer. Near by, in a C. S. ranch pasture, 1 square rod gave a count of 196, or over 20,000,000 to the square mile. August 30, in another pasture, two miles from this last count, an area of average infestation showed 126 to the square rod.

By a very conservative estimate, the total infested area in 1909 was at least 15,000 square miles. It may have been much greater. With an average of 10 caterpillars to the square rod (a conservative estimate) the total number of the pests would reach 1,536,000,000. The investigations of the past two years would seem to show that nearly all the caterpillars reach the adult stage. Supposing that two-thirds become moths, there would be a billion moths, more than one-third of which would be females, each capable of depositing from 100 to 150 eggs. A little calculation will convince anyone of the tremendous possibilities for harm which the figures given above involve—figures that have not been made at random, or hastily.

In connection with the vast numbers of these caterpillars their size must also be borne in mind. The full-grown larvæ frequently measure $2\frac{1}{2}$ inches in length, with the diameter of a man's index finger. When moving about for food they give an observer the impression of being larger then they actually are. Where they are so numerous that one really has to choose his steps to avoid crushing these huge, spiny, ugly caterpillars at every move, the sensation produced by them is peculiar and lasting, especially after walking for miles through their myriads.

FATAL EFFECTS OF HEAT ON LARVÆ.

The extreme sensitiveness of the larvæ of Hemileuca to the heat of the sun's rays was often noticed, and a series of experiments was undertaken to learn if this tendency to avoid the sunlight arose from fear or merely from dislike. Numbers of individuals of varying ages were at different times placed on smooth bare ground that had been heated by the cloudless sun to a warmth that was disagreeable to the bare hand. As no thermometer was within reach the exact temperature could not be ascertained. The larvæ invariably showed signs of distress, almost at once, and began to scramble as rapidly as possible for the nearest shelter. In some cases they would die before moving an inch, and only in rare instances did any survive where the distance to be traversed equaled 24 inches. Larvæ of the fourth and fifth stages showed greater vitality and could travel farther than smaller forms, but even they would always succumb to the sun's heat if compelled to remain on the hot earth for a fraction of a minute.

July 5, 19 third-stage larvæ were placed on the earth 12 inches from the nearest shelter. Several collapsed almost instantly, scarcely

moving at all. Only one or two of the most vigorous reached the shade, and these died immediately when returned to the sunlight.

These repeated experiments proved conclusively that the universal habit of the species of seeking a position on a weed or grass stem, above the surface of the ground and if possible on the shady side of the stem (see fig. 43), has been adopted as a means of self-preservation.

FIG. 43.—The New Mexico range caterpillar: Larvæ clustered on weed stem, to avoid the heated surface of the ground. (Original.)

FOOD HABITS AND FOOD PLANTS.

The habit of ascending any plant that will raise the larvæ of the Hemileuca from the heated surface of the ground has given the species the reputation of feeding on alfalfa, cereals, and weeds of various sorts. It can be safely asserted that they eat nothing but grass, and only the native grasses. Individuals were at different times placed upon timothy, bluegrass, and various grains, wheat, oats, and barley, but they refused them entirely.

The caterpillars feed on most of the native grasses that are found in northeastern New Mexico, the Bouteloua group being their first choice. The list given below was prepared by gathering samples of the grasses on which these pests were actually feeding, and, in cases of doubt, sending this material to the Department of Agriculture in Washington for determination. The list is by no means complete, but comprises the main food plants of the species.

List of food grasses of the range caterpillar, Hemileuca oliviæ.

Hairy mesquite grass (*Bouteloua hirsuta*).
Grama grass (*B. oligostachya*).
Racemed Bouteloua (*Atheropogon curtipendula*).
Buffalo grass (*Buchloe dactyloides*).
Hair-grass dropseed (*Sporobolus airoides*).
Hilaria cenchroides.
Hall's beard-grass (*Andropogon hallii*).
Texan timothy (*Lycurus phleoides*).
Marsh spike-grass (*Distichlis spicata*).
Sitanium jubatum.
Blue-joint (*Agropyron smithii*).
Hordeum cæspitosum.
Brome-grass (*Bromus polyanthus*).

THE PUPÆ.

PUPATION.

The caterpillar when full grown becomes exceedingly sluggish in its movements, and for a day or two hangs inert from a weed stem or travels slowly about looking for a convenient retreat in which to transform to the pupal state. The color, chiefly yellow during the

last instar because of the multitude of small, flattened, yellowish tubercles with which the body is covered laterally, now darkens and becomes a dingy green that renders it very inconspicuous among the grass. Where low, bushy weeds abound, as in most of the range country, the larvæ seek shelter in them, preferring the smaller weeds for this purpose. Where the weeds grow large, the central branches are selected and the larvæ concentrate there.

The pupating caterpillar soon incloses itself within an open-meshed network or reticulum of strong, very uneven silk fibers, and this web is usually finished in twenty-four hours. This is the only attempt at a cocoon made by very many of the larvæ; but 50 per cent or more of the larvæ inclose this coarse web in a closely woven sack of much finer silk, open at the top. (See fig. 44.) The structure of the inner cocoon is so open that the larva is able to protrude its head and construct the finer one outside.

FIG. 44.—The New Mexico range caterpillar: Single cocoon on Gutierrezia. Reduced. (Original.)

Pupation takes place within a few days or hours after the larva has inclosed itself. Occasionally the larva lies dormant for a week before transforming, but usually the change takes place within a day. The pupa gradually changes in color from light brown to a very dark, almost black hue, with dull purplish reflections in some cases.

In localities where the larval food supply is insufficient and the vitality of the larvæ is low, some of them live only through the spinning process and die without being able to pupate. The percentage that thus fails to pupate is difficult to estimate, but is probably much less than 1 per cent.

One curious fact that deserves mention here is the habit, very common where the caterpillars have been numerous, of two and even three pupæ occupying the same cocoon. Twin pupæ are met with everywhere, and often a single plant will contain several examples. Where this doubling occurs there is no attempt at a partition in the pupal chamber, nor is the space allowed for the twins or triplets much, if any, greater than where a single pupa lies alone. It is sometimes possible at a glance to detect the presence of more than one pupa by the greater density of the inclosing web, showing a community of effort. In rare instances two of the reticula are surrounded by a common silk sac.

Where weeds are not available for pupation, clumps of grass are used, their stems being often drawn together by a mass of webs until they resemble in shape an Indian tepee. When both weeds and grass stems are wanting, the larvæ burrow under the short grass close to the ground and draw the blades together for what little protection they will afford.

The silk spun into these cocoons is of a dirty white or even brownish color, and is always lumpy and uneven.

The number of pupæ that are packed away in the weeds in the manner above described is almost incredible. The so-called "snake-weed" or "sheepweed" (*Gutierrezia* [sp.), common everywhere on the range and a favorite plant for both oviposition and pupation, has been observed packed so full of pupæ that from a plant that could easily be contained in a quart measure more than fifty pupæ have been taken. (See fig. 45.)

FIG. 45.—The New Mexico range caterpillar: A charasteristic mass of cocoons in a single plant of Gutierrezia. Reduced. (Original.)

During September, 1909, large areas, covering many square miles, were observed in which all the weeds and bunches of coarse grass were literally filled with the cocoons and pupæ of the Hemileuca. When the moths emerged in such locations they swarmed in countless numbers at dusk.

Previous to the season of 1909 nothing was known definitely concerning larval or pupal history, and no dates could be given. August 18, 1909, a larva was found in the vicinity of Koehler, N. Mex., beginning to spin its cocoon, the earliest example seen during that

year. After that date pupation very rapidly became general over the entire range country and continued until after September 20, at which date a few larvæ were still found to be feeding.

Without doubt abundance or scarcity of food hastens or retards the date of pupation, since this is a potent factor throughout the whole life history of this species of Hemileuca. Near the foothills, where showers were more or less frequent and grass abundant, pupation began twelve days earlier than on the dry mesa in the vicinity of Springer, 30 miles distant, where rain fell but seldom during the summer of 1909, and the grass was correspondingly short.

Although the time of pupation is a critical one in larval life, conditions are so favorable in New Mexico during the summer season that very few out of the millions that undergo the ordeal fail to pass it successfully. The singularly dry air with its warm day temperature seems to afford exactly the conditions that are needed.

LENGTH OF PUPAL STAGE.

The duration of the pupal stage varies greatly, owing to causes not wholly explained. Several individuals, taken and kept in confinement from the time the caterpillar was full fed, disclosed adults within about five weeks after the pupa was formed.

Others again, kept under very similar surroundings, remained as pupæ for seven and eight weeks, even longer in a few instances. No moths emerged in less than five weeks, and this period must be taken as the minimum, with perhaps nine weeks as the maximum.

THE MOTHS.

EMERGENCE.

The great majority of the Hemileuca moths emerge from the pupæ early in the morning, as soon as the chill of night has gone. Upon leaving the cocoon they make their way at once to the upper or outer part of the plant in which they have passed the five weeks of pupal life. Clinging to a stem or twig, they rock the body to and fro, if there is no air stirring, and rapidly dry their limp wings. At first the wings are thrown back from the body until they become firm and normal, then they are roofed closely over the back in the position shown in figure 42. This is the customary resting attitude of the species. The secondaries are often advanced beyond the primaries until the costal margin shows slightly.

The freshly emerged moths remain perfectly quiet during the day (Plate IV, fig. 1), except when, as occasionally happens, a sudden gale from the foothills drives them to take shelter in the lee of their plant, for they seem to have a great dislike for wind.

If the moths are disturbed on this first day of adult life, the female promptly voids the contents of her defensive sac (as described else-

where, p. 87), bringing her body forward and up as she does so. The male will at first wriggle and rock his body, rotating his head in a very peculiar fashion, intended perhaps to inspire terror in the intruder. If the annoyance continues or becomes more severe, he curls the body forward and ejects the milky fluid with some force. When this action fails to remove the disturber, the moths often release their hold, fall to the earth, and "play possum."

They are with great difficulty induced to walk to some other part of the plant on which they are resting.

About 4.30 in the afternoon the male moths begin to stir. The antennæ wave slightly and presently the wings are spread little by little until they lie out flat. Soon the wings are in rapid vibration, for a few seconds at a time, after which they may be partly folded and the moths become quiet again. But very soon the insect grows wide awake, takes a few jerky steps, hesitates again, then runs to the top of the stem on which he has been resting, and launches himself for his crepuscular flight.

The female is much more deliberate in her movements and rarely takes to wing before 5 p. m. She indulges in the same halting preliminaries as the male, but when she finally flies she rises gradually, often to a height of 30 or 40 feet, appears to get her bearings, then sails off in a straight line from which she seldom or never deviates.

For some unexplained reason many of the females fail to mate where they emerge, and these virgin females are the ones that fly to distant parts of the range, carrying their eggs, which are probably fertilized by roving males, and are deposited in hitherto uninfested regions. It is possibly those individuals that emerge from the pupæ earliest in the morning that fly in this manner, while the ones emerging later remain on the natal plant until found by the male.

October 16, 1908, a number of females, perhaps 20, were moved, late in the afternoon, to one plant for better observation. Between 5 p. m. and dusk every member of this colony rose in the air and disappeared, not one having attracted a mate, although males were numerous all about. The same experiment was tried several times during both 1908 and 1909, with the same result, while mated couples (see fig. 46) were everywhere clinging to the weeds.

When the male, hovering in the air, discovers a virgin female he drops to the ground or alights below her on the stem and runs up, his wings in rapid vibration, until she is reached, when copulation takes place immediately. Owing to the predominance in number of the males there is often much strife over the possession of a mate, and frequently six or more males are seen fluttering about a single female.

On two different occasions during the progress of these investigations a male moth was found mated with a spent female which had

discharged her supply of eggs, attention having been first directed to them by the worn and ragged appearance of the wings of the female thus found. The females that take to wing before mating and alight in the borders of, or outside, infested territory, must necessarily mate with worn wings, since their long flight must have its effect on their appearance.

A table on page 88 gives the results of a large series of dissections which seem to prove the existence of more males than females wherever examination was made. During the first week of emergence in 1909 the males outnumbered the females at least three to one.

The date of the beginning of adult emergence in former years is not known. In 1908 the moths are said to have appeared about October 1. In 1909 the first adults, two males, were seen October 1, and it is probably safe to consider this as the average date of emergence.

FIG. 46.—The New Mexico range caterpillar: Moths mating. Reduced. (Original.)

The adults continue to appear until the middle of November, unless, as in 1909, the cold and snow put an earlier stop to their emergence. As far as can be learned from residents of New Mexico, no belated Hemileucas appear in the spring, but all that fail to emerge in the fall perish, in the chrysalis, during the winter.

The life cycle of the species is illustrated by figure 47.

CHARACTER OF FLIGHT.

When fairly on the wing the flight of the Hemileuca moths is strong and persistent. The males are much more active than the females, and are at times very difficult of capture except by strategy. They usually fly near the ground, moving across the country by a series of zigzag back-and-forth flights, always working into the wind and never alighting except in the immediate neighborhood of a virgin female. They carefully reconnoiter every plant, and fly especially about the tallest objects in the landscape as they search closely for the female, guided, apparently, by odor. A person standing erect is the object of much of their attention, and the swarm of "purring"

males that gathers about one's head frequently becomes a nuisance by reason of the persistence of the moths composing it.

Under certain conditions the males, when disturbed in their search, will rise high in the air and fly away in a straight course, horizontally, exactly as do the females.

The flight of the females is very different from that of the males. From the moment of launching from the weed-top into the air the female seems to steer a definite course, and seldom varies at all from the direction chosen at the start. This course is usually with, or at a slight angle with, the wind, although some evenings they will fly continually directly across the breeze or even against it. The flight is all in one given direction as a rule on any one evening.

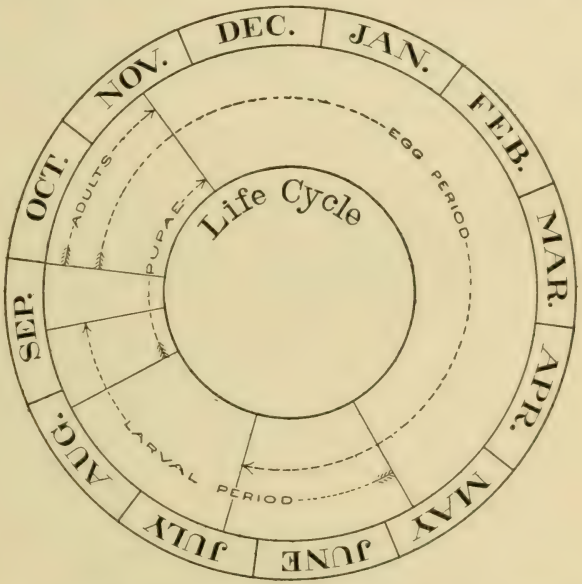

FIG. 47.—Diagram illustrating life cycle of *Hemileuca oliviæ*. (Original.)

How far the females travel, carrying their eggs, is largely a matter of conjecture, but as they fly at the rate of 8 to 10 miles an hour, with a somewhat heavy but strong muscular action, there seems good reason to believe that they traverse long distances before they alight.

The fluttering myriads of moths that appeared during October, 1909, were present over very wide areas in almost incredible numbers, day after day. Taking into account the fact that the life of the individual moth rarely if ever exceeds three days, the successive multitudes, practically undisturbed by enemies, intent solely in providing for the further spread and increase of the species, constitute a menace to the entire range country of the Southwest that needs only to be seen to be appreciated.

ATTRACTION TO LIGHTS.

Under certain conditions, arising possibly from the amount of moisture in the air caused by distant or passing showers, the male Hemileuca moths are attracted to light during their nocturnal flights. At times these moths will swarm on the window screens and then perhaps not one will appear for a week. In the village of Cimarron, one of the famous stations on the old Santa Fe Trail, the numbers of these insects that gathered on screen doors and at lighted windows were extremely annoying. But this swarming occurred only two or three times during the six weeks of the flight of the species.

When attracted to a lighted window at night the moths remain there, if undisturbed, until the regular hour for the next day's flight, when they rouse themselves and take to wing as usual. The moths confined within a room grow restive and fly just before sunset, their instinct informing them of the arrival of the time to move.

FLIGHT DURING STORMS.

Moths of both sexes often fly during a downpour of rain, more especially the males. Even cold fails to check their flight, and numbers have been seen actively darting about when the mercury was close to freezing point. In one or two instances they have been seen flying during a snow storm.

Continued cold, however, is fatal to them. In October, 1908, after a series of snow squalls, when the ground had been white for a day or two, hundreds of dead males were lying scattered about the pastures. In several cases noticed, as many as 25 or 30 males lay dead about a single plant of snakeweed (*Gutierrezia* sp.) where they had taken refuge from the storm.

Dead females are much less frequently seen, though they sometimes perish with cold while endeavoring to oviposit.

COLOR AS AFFECTED BY CHANGES IN TEMPERATURE.

Great and unusual changes in temperature during the pupal stage appear to affect to some extent the colors of the adult. October 20 and 21, 1908, a fall of snow on the infested range was followed by a temperature several degrees below freezing point. The emergence of the moths was at its height when the snow came, but was almost wholly checked for several days by the cold. When the weather again became warm and fresh moths appeared, they were noticeably lighter in color and with much less definite markings than those that had emerged previously. After a few days of warm weather, the moths as they emerged possessed their normal colors and markings.

Few, if any, of those moths that were living when the snow came survived the severe cold, and the dead moths were seen on the ground by the thousand; mostly, however, males. Hence those that appeared after the snow were fresh from the chrysalis.

DEFENSIVE METHODS.

Every moth of this species, when it emerges from the pupal case, contains within its abdomen a sac of defensive fluid. This sac is situated near the tip of the body and the included fluid is white or milky in appearance. If the moth is touched or thrown from its perch to the ground, its first instinctive movement is to throw the wings back from the body and to bring the abdomen forward until its extremity almost touches the face. The contents of the sac are then discharged, sometimes with considerable force, by a series of impulses that empty it entirely. If the sac has already been unloaded the moth will lie as if dead for some minutes unless the heat of the sun compels it to seek a cooler place. Even when nearly dead from cold, the moth, when disturbed, invariably throws back the wings and curls the body forward, as described.

When the moment for flight has arrived, the moth, if previously undisturbed since emergence, always discharges the fluid from the sac as a preliminary act before taking wing. This habit affords a method for determining with certainty whether any given moth has been in the air.

The male always discharges this fluid before mating, since he invariably flies in search of his mate. The female does not always rid herself of the contents of the sac at the approach of the male, but seems compelled to do so before oviposition.

It is one of the peculiar facts known of this species that it should be so well equipped for defense against enemies that do not appear to attack it in its present mode of existence. It may be a survival of defense that was once needed and of habits that were acquired in some previous phase of its life, before the species became graminivorous.

NATURAL ENEMIES.

INSECT PARASITES.

During the month of September, 1909, large numbers of pupæ of Hemileuca were collected and dissected to ascertain if possible the extent and success of parasitic attack. These gatherings were made from somewhat widely separated parts of the infested district, and probably give as fair a general view of existing conditions as could be obtained.

The results are tabulated as follows:

Parasitism of pupæ of the range caterpillar (Hemileuca oliviæ).

Total pupæ.	Male.	Female.	Living.	Dead.	Parasites.
500	303	197	453	47	5
1,764	947	817	1,709	55	6
800	563	237	744	56	8
416	213	203	402	14	6
1,300	675	625	1,243	57	5
200	109	91	182	18	.....
20	12	8	18	2	.....
5,000	2,822	2,178	4,751	249	30
Percentage	56.4	43.5	95	5	0.6

The parasites found are classified as follows:

Pimpla conquisitor[a] Say	1
Pimpla sanguinipes[a] Cress	8
Chalcis ovata Say (larvæ and pupæ)	12
Tachina mella Walk. (larvæ and pupæ)	6
Unclassified (probably hymenopterous)	3
Total	30

One Hemileuca pupa contained two pupæ of *Chalcis ovata*. Usually this parasite occurs singly, and is found altogether in the head end of the host pupa, through which it bites an irregular hole for its escape.

The Diptera-infested pupæ contained in one case three pupæ of parasites, in another case four, while a deformed Hemileuca pupa contained a single dipterous larva.

Chalcis ovata Say.

The well-known and widely distributed lepidopterous parasite *Chalcis ovata* Say (fig. 48) is present in New Mexico, in limited numbers, and is to some extent an enemy of the Hemileuca. It attacks the chrysalis, its larva being found in the upper or head end of the pupa of the Hemileuca, and emerges during October, at about the same time as the Hemileuca moths appear. The injury it inflicts seems to be very slight. Among 5,000 pupæ examined, only 12 were found to have been killed by this chalcidid. After its emergence, the adults of *Chalcis ovata* are found in some abundance about the plants of *Opuntia arborescens*, or some closely allied species of cactus, but little seems to be known of the life and habits of this parasite in this region.

Pimpla sanguinipes Cress. and **P. conquisitor** Say.

An examination of 5,000 pupæ gathered from various parts of the range country disclosed the fact, before unsuspected, that two species of ichneumons were engaged in destroying the larvæ of Hemileuca. The effect of these in checking the multiplication of these range caterpillars was exceedingly small and insignificant, as in the entire 5,000 pupæ but 9 individuals were found containing ichneumon larvæ. Several adults were reared, most of them belonging to *Pimpla sanguinipes* (fig. 49). A single female, however, belonged to *P. conquisitor* (fig. 50). A hyperparasite upon either one or both of these species of Pimpla was reared in some numbers and determined by Mr. J. C. Crawford as *Dibrachys* sp.

[a] Larvæ large, tapering, nearly filling the Hemileuca pupal case.

Tachina mella Walk.

Between July 17 and the middle of August, 1909, many Hemileuca larvæ were found to be infested by the eggs of a dipterous parasite. These eggs were never deposited on the smaller forms of these larvæ, but always on those nearly full grown.

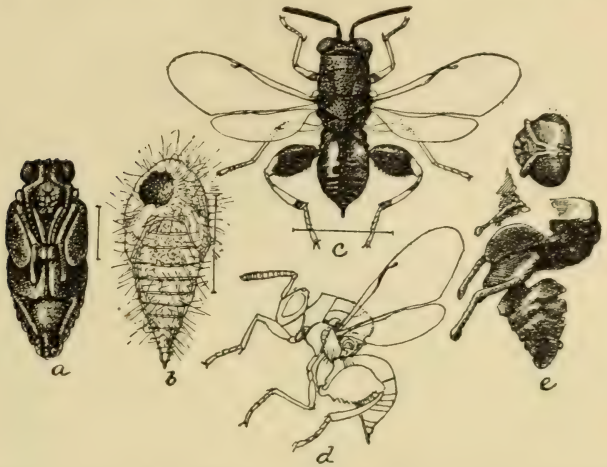

FIG. 48.—*Chalcis ovata: a*, Pupa; *b*, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); *c*, adult; *d*, same, in profile; *e*, pupal exuvium. Enlarged. (From Howard.)

They were, in nearly every instance, deposited on the sole of the prop-foot, within the crescent of hooklets with which these feet are armed, a few eggs being found attached laterally to the thorax.

FIG. 49.—*Pimpla sanguinipes:* Adult. Enlarged. (Original.)

A large number of these infested larvæ were placed in confinement, and the adult fly secured. The species has been determined by Mr. D. W. Coquillett as *Tachina mella* Walk. (See fig. 51.)

These flies seemed to be well distributed over the range, but in very small numbers, judging from the scarcity of the eggs that were found.

Elsewhere is given a description of the method of attack used by the fly in avoiding the larval spines during oviposition.

The pupal period of these flies is sixteen days. No data for the length of the larval period could be obtained.

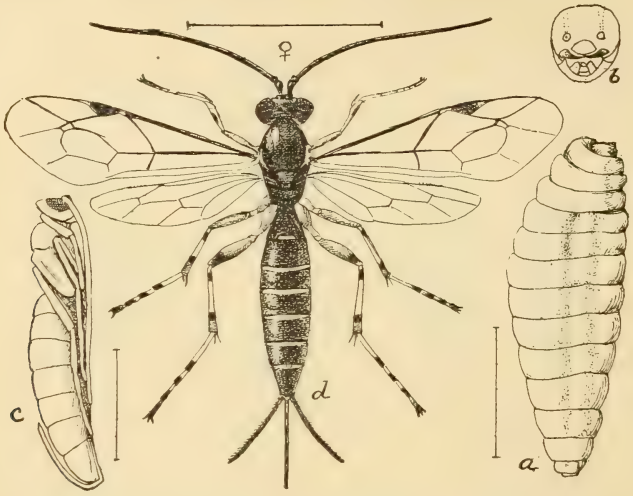

FIG. 50.—*Pimpla conquisitor:* *a*, Larva; *b*, head of same; *c*, pupa; *d*, adult female. Enlarged. (*d*, Original; *a*, *b*, *c*, redrawn from 4th Rep. U. S. Ent. Comm.)

After eggs of this tachinid had been observed on a number of Hemileuca larvæ, near the end of July, the first example being seen July 17, 1909, an effort was made to observe the method of oviposition employed by the fly. Some 400 larvæ were collected and assembled on a large detached sod of *Sporobolus airoides*, a favorite food grass.

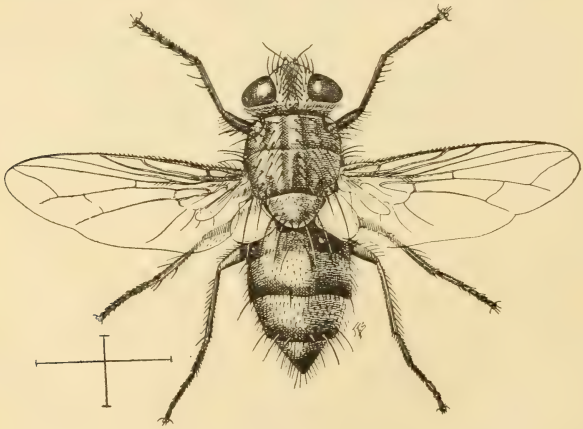

FIG. 51.—*Tachina mella:* Adult. Enlarged. (Original.)

These larvæ were watched closely for several days, and on July 26 a tachinid fly was seen in the vicinity of a large caterpillar that was resting quietly on a grass stem and feeding leisurely at intervals. The attitude of the fly was peculiar, and attracted attention at once. She stood about 4 inches from the larva, facing it, her antennæ

standing out stiffly horizontal in front of her face. After a minute of silent attention she moved carefully toward the worm, gliding over the intervening grass blades with a stealthy step much unlike the usual walk of these large flies. She maneuvered about the caterpillar with quick, nervous, jerky steps, keeping well below the body of her victim. The abdomen of the fly all the while moved slightly, as if the ovipositor were being made ready.

At last the caterpillar found it necessary to move to fresh pasture. Its true feet crept along the stem and as the movement swept back through the clumsy body the fly ran nimbly up below, ovipositor extended. As soon as the thick prop-feet were lifted, the ovipositor curved quickly upward once or twice, but things were not quite right and there was no contact. The fly ran along the grass blades to the larva's head, got in front of it, and once more stood facing it for some minutes. The larva finally seemed to realize its danger and showed its annoyance by a few quick jerks of its head and body, apparently intended to scare away the intruder. But the fly held her ground, with now and then a quick step or motion, followed by rigid quiet. The larva at last became quite uneasy and began to walk off, whereupon the fly again ran below. The ovipositor was thrust swiftly upward several times, but the prop-feet did not seem to open enough to allow of the placing of any eggs. The fly soon after grew weary, walked carelessly away, and was about to take wing when she was captured. Her wings were much worn and ragged and she appeared to have spent her supply of eggs before this attack. She lived but a few hours in captivity.

No eggs had been deposited on the larva during the attack, possibly because conditions were not quite favorable. But the nature of the attempt explained the finding of these dipterous eggs almost always on the inner surfaces of the prop-feet, probably because this was the one vulnerable spot in the whole anatomy of the caterpillar.

The attack of the tachinid fly is often futile because the egg, after being placed on the body of the larva, is likely to be shed with the next molted skin, before hatching. The question may also be raised whether the newly hatched tachinid larva is always able to penetrate the tough, leathery body of its host. In almost every case the eggs that were found had been placed within the crescent of hooks that fringe the outer rim of the prop-feet, and were thus on the fleshy pad or sole of these feet. In some instances, where the Hemileuca caterpillar, with the eggs placed on the feet as described, was placed in captivity and the parasite reared, it was proved that the young of the fly had in some manner been able to effect an entrance to the body of the host. Eggs laid upon the sides of the thorax did not, as far as known, injure the caterpillar upon which they were placed.

August 17, 1909, a full-grown Hemileuca larva, bearing two tachinid eggs in a fold of the skin near the anterior pair of prop-legs, was taken in the vicinity of Koehler, N. Mex. This infested individual was placed in a small box, where a week later it was found in the act of making its crude cocoon. It pupated and five weeks later a perfect moth appeared. This attack, made under the most favorable circumstances, proved wholly abortive.

It is possible, of course, that these flies choose the prop-feet as points of attack because the body above is too well defended by its forest of needle-like spines to permit of successful approach. Even if this is the case, it is a little strange that eggs are not found elsewhere below than on the prop-feet, that are accessible to the fly only when the caterpillar steps.

Not infrequently, during August, molted skins were found to which were attached 1, 2, and even 3 tachinid eggs, generally fresh. In one case an egg was found on a freshly cast skin, and one on the newly emerged larva that was standing close by, showing that the fly had remained on duty during the operation of molting.

OTHER TACHINID PARASITES.

A single adult of *Euphorocera claripennis* Macq. (fig. 52) was reared from the range caterpillar. *Siphoplagia anomala* Towns. was observed among the Hemileuca larvæ but no adults were reared from them. *Winthemia quadripustulata* Fab. was a common parasite on *Heliophila albilinea* in the same locality, but did not seem to attack Hemileuca larvæ, as none was reared therefrom.

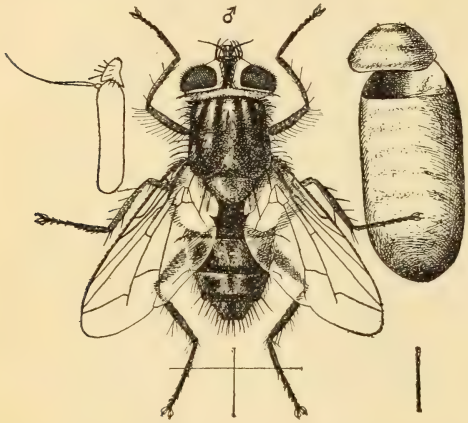

FIG. 52.—*Euphorocera claripennis:* Adult and enlarged antenna of same, puparium. Enlarged. (From Howard.)

OTHER INSECT ENEMIES.

August 12, 1909, near Koehler, N. Mex., a robber fly, *Stenopogon picticornis* Loew (fig. 53), was observed attacking a Hemileuca caterpillar and feeding upon it. Subsequently a number of dead larvæ were found in locations where these flies were numerous, and the presumption was strong that the flies had caused their death, although none was seen actually attacking the caterpillars. The dead larvæ were noticed over a comparatively limited area and the robber-fly attack appeared to be local.

October 11, 1909, a female Hemileuca moth was seen, on the Captain French ranch, a captive of one of these robber flies (*Erax varipes* Will.). The large dipteron was half running, half flying, with its bulky prey and was making its way rather rapidly across the country. This was the only instance seen of any sort of attack upon the adult Hemileucas during observations covering two years of the adult period, with hundreds of thousands of moths under close study during that time.

FIG. 53.—Robber fly, *Stenopogon picticornis.* Not quite twice natural size. (Original.)

MITES.

A small red mite, *Rhyncholophus* sp., occurs at times on the Hemileuca larvæ, but seldom in any great numbers. As many as six have

been observed at one time feeding on a single larva, but only a comparatively small percentage of the larvæ are infested. These mites are, of course, shed with the molted skin, but they are quite active and soon regain a new location on some near-by host. It is probable that they are merely a source of some irritation to their hosts and do them no particular injury.

ANTS FOUND IN PUPAL SHELLS.

Empty pupal shells are occasionally found on the infested parts of the range swarming with very minute glistening ants that are quite sluggish in their movements. There is no indication that these ants ever attack perfect pupæ, but probably they act merely as scavengers when a pupa is thrown from its web and broken. These ants appear to be somewhat common everywhere throughout New Mexico. Specimens were submitted to Dr. W. M. Wheeler and determined as *Monomorium minutum* Mayr, var. *minimum* Buckley.

BIRDS.

On July 27, 1909, two robins were seen, each with a Hemileuca larva in its bill. The birds flew away with these in the direction of shrubbery along Cimarron Creek, as if intending to feed the caterpillars to their young. The next forenoon it was learned by the aid of a field glass that several robins were busy in that vicinity, not only carrying the worms across the fields, but occasionally eating them. A close watch was maintained on meadow larks, blackbirds, and several other species of birds, but none of these was seen to attack or feed upon the caterpillars. Robins are not at all numerous in northeastern New Mexico and are a very small factor in the control of the Hemileuca throughout the infested district, especially as they seem to feed only on the smaller larvæ. The spines of the larger larvæ are capable of producing much greater urticating effect and are possibly disagreeable to the birds on that account.

EFFECTS ON THE RANGE CATERPILLAR OF PASTURING.

Infested pastures have as a rule very few cattle during the larval and pupal periods of Hemileuca life, for the large herds of the region are kept in the mountain pastures through the summer and brought to the lower levels late in the fall to eat the sun-cured grass during the winter. In some cases, however, cattle and horses pasture the low mesas in the summer time and do the Hemileucas some harm, especially during the pupal period. Many pupæ are thrown from the cocoon to the ground by the feet of animals striking the weeds in which the cocoons have been placed. Some of these dislodged pupæ undoubtedly perish, but unless lying directly exposed to the heat of the sun or crushed by passing feet the majority of those on the

ground probably produce moths as readily as those remaining in cocoons, on account of the peculiar climatic conditions that prevail and the almost total absence of moisture in the soil.

REMEDIAL MEASURES.

A series of questions addressed to a number of the prominent residents and ranch owners living in the infested territory was sent out in the form of a circular letter during the summer of 1909. An effort was made in this way to ascertain, if possible, the year when the range caterpillar was first observed, the amount and extent of injury resulting from its outbreak, and the remedies, if any, that had suggested themselves to those most interested in destroying the pest. The replies to the first two queries were so contradictory and vague that little was learned. Regarding remedies, the majority of the writers had nothing to propose. A few thought it possible that some insect might be introduced that could control or do away with the pest, but the remedy that appealed to most of those who had studied conditions was that of burning.

BURNING THE RANGE.

At the beginning of the outbreak, especially if the insect originated from one common center—a fact that may be open to serious question—concerted action in the matter of burning over the infested area might have succeeded in banishing the pest from the region. At the present time, however, burning the range would be only a temporary and local expedient. It must be borne in mind that where the infestation is the most severe there is usually insufficient grass remaining to support a running fire. The small value of the range per acre for pasturage would hardly warrant, except in the direst necessity, the expenditure of funds sufficient to make sure of reaching every part by fire.

An experiment in this line was tried in the spring of 1909 and a large area in a wild pasture near Koehler was burned over. Within this burned area, later in the season, the number of caterpillars equaled those on the surrounding unburned parts of the same pasture. Either multitudes of the eggs escaped the heat of the fire or the caterpillars spread over the burned district from the unburned portions nearest at hand. A hailstorm that swept over part of this same pasture in June, 1909, failed to kill more than a few of the millions of worms that were feeding in its path.

In view of the fact that the infested territory at present extends over 10,000,000 to 15,000,000 acres or more, it will be seen that fire as an agent of destruction could be only local and palliative, for the

gap that it might make in the ranks of the invading hordes would soon be closed by successive broods that would appear in unburned sections.

INTRODUCTION OF NATURAL ENEMIES.

The matter of the introduction of parasitic insects for control of the Hemileuca will probably be investigated further.

The importation of birds to feed on the caterpillars has been suggested, but in the infested regions the wide treeless plains afford but little encouragement for nesting birds. Besides this, it is a lamentable and criminal fact that in spite of laws that are designed for the protection of bird life in New Mexico, a constant and indiscriminate slaughter of all sorts of birds is in perpetual progress until the companionable species and those of high economic importance have been practically exterminated in many parts of the Territory. This condition of things may possibly account, in some measure, for this Hemileuca invasion, and may in the not remote future bring into prominence other insects now few and harmless, but multiplying because their bird foes have perished at the hands of the hunter. This bids fair to become a serious matter, and not alone in New Mexico.

ROLLING THE GROUND.

Rolling the surface of the country to crush the larvæ has been suggested, and even using some sort of oil-burning apparatus that would surely destroy all the eggs or larvæ within a given area. The roller has never been tried in an actual experiment, but it is obvious to one familiar with the region that the surface is too uneven to justify hopes for the destruction of more than a small percentage by this method.

THE CHIEF DIFFICULTY IN APPLYING REMEDIAL MEASURES.

Another and more serious objection to any scheme of destruction that involves either labor or expense is found in the extremely small value per acre of the grass crop. When land rents for from 2 to 5 cents per acre for the year's pasturage it would not be reasonable to expect any party interested to expend a very large sum per acre, even to destroy a range pest. The aggregate damage resulting from the attack of the range worm is enormous. But such large areas are involved that when the loss is reduced to the acre unit it seems entirely out of the question to the large ranch owners to involve themselves in any method that aims to destroy the range worm by expensive means. From their standpoint, it would be better to go out of the cattle business and let the worms take the range than to spend the income of a series of years in a doubtful experiment.

This argument, which is a common one, puts an end to all mechanical means of control of this pest, except possibly as a federal measure, at public expense, and leaves the matter of the introduction of insect parasites as perhaps the only feasible way to reach a solution of this puzzling question. Continued study may discover other means, but so far as the investigation has been carried no ready relief is yet in sight.

PAPERS ON CEREAL AND FORAGE INSECTS.

CONTRIBUTIONS TO A KNOWLEDGE OF THE CORN ROOT-APHIS.

(*Aphis maidi-radicis* Forbes.)

By R. A. Vickery,
Agent and Expert.

INTRODUCTION.

The corn root-aphis (*Aphis maidi-radicis* Forbes) is one of the many insects infesting the corn plant in this country. It has certainly been known as an enemy of corn for nearly a century, and perhaps much longer. Besides corn it attacks sorghum and broom corn, but does little damage to these plants. Within the last three years it has attracted considerable attention as an enemy of cotton in the Carolinas, where it feeds on the roots of young cotton and is called the "root louse" or "blue bug." Among its other recently ascertained food plants are pumpkin, squash, strawberries, cultivated asters, and perhaps dahlia and French artichoke.

Ever since this insect was first noted by Walsh in 1862 it has received considerable attention from economic entomologists. Its life history and habits in Illinois have been very thoroughly studied by Dr. S. A. Forbes, state entomologist, and his assistants; and during the past three years it has been studied, under the direction of Prof. F. M. Webster, by the assistants in Cereal and Forage Insect Investigations, Bureau of Entomology. These studies have been made over a large extent of country, as follows: In the Northwestern States during the season of 1908 by Mr. E. O. G. Kelly; in Indiana by Mr. W. J. Phillips; in South Carolina during the seasons of 1908 and 1909 by Mr. G. G. Ainslie;[a] in Florida and eastern North Carolina, as a cotton insect, by Mr. H. F. Wilson under the direction of Mr. W. D. Hunter, during the season of 1909; and in the Piedmont section of North Carolina by the writer, also during the season of 1909.

[a] These investigations were carried on by Mr. Ainslie as a part of cooperative work by the Bureau of Entomology and the South Carolina experiment station of the Clemson Agricultural College, and the results of his work were published by Prof. A. F. Conradi in the twenty-second annual report of that institution, for the year ending June 30, 1909, pages 51 to 65.

An aphis frequently infesting the roots of *Erigeron canadensis* has generally been considered as belonging to this species. It is included in the latter part of this paper for this reason, but, as explained farther on, it now seems to be distinct from the corn root-aphis, and is therefore discussed under the name *Aphis middletoni* Thomas, with the description of which it seems best to agree.

The illustrations of the oviparous female and wingless male of the corn root-aphis (figs. 56 and 57) are kindly loaned for use in this paper by Dr. S. A. Forbes, state entomologist of Illinois.

DISTRIBUTION.

According to the letters of inquiry in the files of the Bureau of Entomology the corn root-aphis has been seriously injurious to corn in the following States (fig. 59): New Jersey, eastern Pennsylvania, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Ohio, Indiana, Illinois, and Oklahoma. Besides these States it has been reported in literature as injuring corn in New York, Minnesota, Iowa, Missouri, Nebraska, Kentucky, Mississippi, Louisiana, and Colorado. In addition to the States mentioned above the root-aphis was collected from the roots of corn at Sioux Falls, Huron, and Aberdeen, S. Dak., by Mr. Kelly of the Bureau of Entomology, and what is supposed to have been this species was collected from corn roots at Sterling, Kans., by Mr. C. N. Ainslie, also of this Bureau. Injuries to cotton have occurred in the coastal plain of the Carolinas. An aphis supposed to be of this species has been reported to the Bureau as injurious to cultivated asters from the following States: Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Ohio, and Illinois. The species is apparently distributed in the United States throughout almost the entire region east of the Rocky Mountains wherever corn is grown.

It has been reported from Maine in a letter to the Bureau, but on what food plant it was taken is not known. Although Mr. Kelly searched for it in North Dakota, Montana, and Wyoming he did not find it in those States. It has not, up to the present time, been reported from New Hampshire, Vermont, Michigan, Wisconsin, Arkansas, or southern Florida. It is probably present in Mexico, although we have found no reference to it in any of the foreign literature.

HISTORY.

Although the corn root-aphis (figs. 54–58) was not described and named until 1891, it has apparently been known to the corn growers of this country for nearly a century and possibly much longer. James Worth, in an article entitled "Observations on Insects" read before the Agricultural Society of Bucks County, Pa., July 29, 1822,

and published in the American Farmer,[a] mentioned "a species of louse or aphis, that infests grounds and feeds upon the roots of wheat, corn, young trees, etc., and do immense damage." And Thos. W. Emory,[b] in writing of sedge in wheat, said:

> I believe that this insect is the same as that known by the name of root louse in corn, so frequently found in that plant, growing after clover, when the land is early flushed, and which occasions so stinted and diseased a growth that it rarely recovers till late in the summer, and not then if the season is dry.[c]

Mr. Emory gave his address as Poplar Grove, without mentioning the State. But although the State was not mentioned, his writings give the impression that he was talking about conditions in Maryland. From these two notices it appears that the corn root-aphis was familiar to the people of Pennsylvania and Maryland as early as 1822, because there is no other aphis on the roots of corn common enough to have been so generally known.

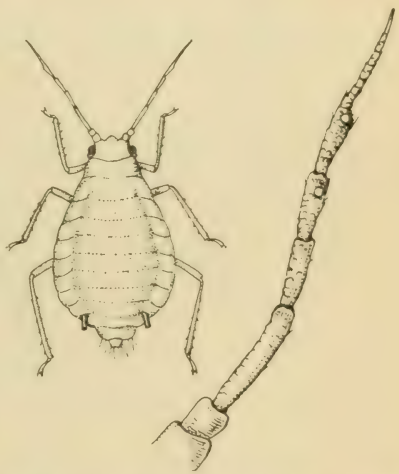

FIG. 54.—The corn root-aphis (*Aphis maidi-radicis*): Wingless, viviparous female, greatly enlarged, and antenna, highly magnified. (From Webster.)

In Illinois the corn root-aphis was first studied in 1862 by B. D. Walsh near Rock Island, where it had attacked a small field of corn and destroyed about half of it. Walsh collected specimens from which he reared winged females (fig. 55), and from the similarity of these to the corn leaf-aphis he decided that they were identical, and in an essay published in the Transactions of the Illinois Agricultural Society he considered the leaf-aphis to be but an aerial form of the root-aphis. This view was accepted by Cyrus Thomas and later writers who studied the species.

Dr. S. A. Forbes began his study of this insect in 1883, and, as a result of his work and the work of his assistants, came to the conclusion that the root-aphis is a distinct species. So he described it as such under the name of *Aphis maidi-radicis*.[d] His studies of

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[a] American Farmer, vol. 4, p. 395, March 7, 1823.

[b] Idem, p. 71, May 24, 1822.

[c] Webster, F. M.—Early published references to some of our injurious insects. Insect Life, U. S. Dept. Agr., Washington, D. C., vol. 2, Nos. 7 and 8, p. 264, 1890.

[d] Seventeenth Report of the State Entomologist of Illinois for 1889 and 1890. Trans. Dept. Agr. Ill., Springfield, vol. 28, pp. 64–70, colored plate "B," figs. 1–4, 1891.

this species have been continued till now its life history and habits as a corn insect in Illinois are very well understood.

Until recently it has not been so thoroughly studied in other sections of the country, especially in the Southern States, where its life history and habits are widely different from what they are in Illinois. Some of the results of these more recent studies which have been made by the Bureau of Entomology are therefore presented in this paper.

EXPERIMENTAL WORK IN THE SOUTH.

The following laboratory experiments were carried on by the writer at Salisbury, N. C., to determine the identity of the aphides

FIG. 55.—The corn root-aphis: Winged, viviparous female, greatly enlarged, and antenna of same, highly magnified. (From Webster.)

found on the roots of corn, cotton, and various weeds. The method used was to remove wingless females of *Aphis maidi-radicis* from the roots of the various food plants and to place them either on sprouting cotton or on sprouting corn in vials. A plug of wet absorbent cotton was placed in the bottom of the vials. The roots of the plants would grow down into this and would keep alive and furnish nourishment for the aphides for about a week. Cotton plants proved the best for use in these experiments because they were not so subject to attack by fungi as were corn plants. The vials were kept in the dark. The aphides usually attack the leaves of the cotton in preference to the stem.

Ambrosia artemisiifolia (bitterweed).—Experiment *a:* Apterous vivipara were removed from the roots of this plant, September 18, and placed on sprout-

ing corn; they reproduced and the colony was kept on corn till November 30. Many oviparous females and 2 winged males were produced by this colony. The sexual forms appeared October 15. Experiment *b:* Apterous vivipara were removed from the roots of Ambrosia and placed on sprouting cotton, September 24. The colony continued till November 16, producing oviparous females October 28.

Chenopodium album (lamb's-quarters).—Two vivipara and 1 oviparous female were removed from this plant to sprouting cotton. This colony did well till November 11, when the 2 oviparous females it contained were removed to alcohol.

Diodia teres (buttonweed).—Experiment *a:* Female specimens were removed from the roots of this plant to cotton, July 29; the colony did well till August 10, when it was killed by the death of the cotton plant from disease. Experiment *b:* Wingless females were removed to corn, July 28. Young were produced and the experiment was continued till August 30. Experiment *c:* Seven wingless females, which had produced young on corn in experiment *b*, were removed to cotton, August 14. They produced young on the cotton and the colony was continued till November 22, when it was discontinued. No sexual forms were produced.

Diodia virginiana (buttonweed).—Female individuals were removed from the roots of this plant to sprouting cotton, September 25. The colony did well till December 4, when it was discontinued. No sexual forms were produced.

Leptochloa filiformis.—Experiment *a:* Females were removed from the roots of this plant to sprouting cotton, September 13. The colony was continued till December 8 without producing sexual forms. Experiment *b:* Females were removed from the roots of Leptochloa to corn. This colony continued till December 4. Oviparous females and a winged male were produced, and eggs were laid.

Corn.—Wingless females were removed from the roots of corn in the field to sprouting corn in a vial, June 16, and on July 15 females were removed from the corn in this vial to sprouting cotton, where they established a colony which was continued till August 16.

These experiments show that if the apterous females of *Aphis maidi-radicis* are transferred to the roots of corn or cotton from several of their wild food plants or if they are transferred from corn to cotton they will produce young and establish colonies. Thus it is possible for the ants to transfer the aphides from a dying food plant to any other one of a large range of food plants. Fortunately there are many cultivated plants, such as clover, cowpeas, wheat, oats, and rye, used in various systems of rotation, which this insect feeds on not at all, or only rarely and for a short time.

Mr. G. G. Ainslie experimented in a different manner near Marion, S. C., to determine the same points. Seeds of a number of species of cultivated plants were planted near infested corn rows, trusting to ants to transfer the aphides from one plant to another. These introduced plants were examined June 5, with the following results: Muskmelon plants near infested cotton were well provided with aphides, several of the wingless ones being found with young about them. Turnip plants near infested cotton had few aphides on

them. Cowpeas were lightly infested with all stages, except migrants, although not located near heavily infested cotton. On beans near infested cotton there were only a few of the root-aphis. Sweet corn had been planted along a row of cotton, and this was quite generally infested with the "lice," plants that were near dead cotton being most heavily infested. On radish, a colony was found on one plant growing near badly infested cotton. Watermelon plants which had just unfolded their first leaves and were near infested cotton had an abundant supply of the root-aphis. In the case of each of the cultivated plants mentioned above, Mr. Ainslie found evidence that the "lice" were transferred from the cotton to the others by the ants. The ants found in attendance were *Lasius niger americanus*, *Pheidole dentata comutata*, and *Pheidole vinelandica*.

UNCULTIVATED FOOD PLANTS.

Beside the cultivated plants mentioned above, the root-aphis feeds on various uncultivated species which are enumerated below.

In Illinois it has been reported by Mr. J. J. Davis[a] on the roots of numerous weeds and grasses, as follows: Smartweed (*Polygonum lapathifolium*), knotweed (*Polygonum persicaria*), crab grass (*Digitaria sanguinalis*), purslane (*Portulaca oleracea*), dock (*Rumex crispus* and *R. altissimus*), foxtail or pigeon grass (*Setaria glauca* and *S. viridis*), fleabane (*Erigeron canadensis*), mustard (*Brassica nigra*), sorrel (*Oxalis stricta*), plantain (*Plantago major* and *P. rugelii*), pigweed (*Amaranthus hybridus*), and ragweed (*Ambrosia trifida*).

In the South it has been found on the following wild food plants:[b] At Chattanooga, Tenn., November 25, 1909, a few oviparous females were found on thorny amaranth (*Amaranthus spinosus*). Viviparous females were found on green amaranth (*Amaranthus retroflexus*) in a cornfield at Salisbury, N. C., October 12, 1909, in small numbers. It was found rarely on Roman wormwood (*Ambrosia artemisiifolia*) at Nathalie, Va., by Mr. J. A. Hyslop, July 10, 1908. It was found in large numbers on the roots of *Ambrosia artemisiifolia* in cotton fields and in waste ground at Marion, S. C., May 27 to June 5, 1909, and at Salisbury, N. C., May 22 and September 18, 1909. On this plant they usually fed in fair-sized colonies along the main taproot, sometimes 10 inches deep in the ground. It was found on dog fennel (*Anthemis cotula*) in very large colonies at the base of the large roots, near the crown, at Marion, S. C., on May 29, 1909; on shepherd's purse (*Capsella bursapastoris*) in small numbers at Salis-

[a] Davis, John June—Biological Studies on Three Species of Aphididæ. Tech. Ser. No. 12, Part VIII, Bur. Ent., U. S. Dept. Agr., February 20, 1909.

[b] Records from Marion, S. C., are by Mr. G. G. Ainslie; those from other localities are by the writer, unless otherwise stated.

bury, N. C., June 16, 1909; on lamb's-quarters (*Chenopodium album*) growing near a field of popcorn at Nathalie, Va., by Mr. Hyslop, July 10, 1908, and on the same species growing beside a cornfield at Salisbury, N. C., October 9–22, 1909—in large numbers at both places; on poverty weed (*Diodia teres*) in a cornfield at Salisbury, N. C., July 28, 1909; on buttonweed (*Diodia virginiana*) in a cornfield at Salisbury, N. C., September 25, 1909; on foxtail or pigeon-grass (*Setaria glauca*) at Marion, S. C., June 3, 1909; in small numbers on cudweed (*Gnaphalium purpureum*) at Salisbury, N. C., May 22, 1909, and in large numbers on this plant at Marion, S. C., from May 26 to June 14, 1909. It was numerous on sneezeweed (*Helenium tenuifolium*) at Rockmart, Ga., November 23, 1909, and at Marion, S. C., May 29 to June 25, 1909; this plant, growing in open ground, and in cotton and corn fields, was the most commonly infested weed, and was heavily infested by the aphis in all stages. On pineweed (*Hypericum gentianoides*) it was found in small numbers at Marion, S. C., May 26, 1909. It was abundant on dwarf dandelion (*Krigia virginica*) at Marion, S. C., May 26, 1909; large colonies were found near the crown of the plant, but individuals were sometimes deep down on the fibrous roots. It was found on *Leptochloa filiformis* at Salisbury, N. C., September 13, 1909. On peppergrass (*Lepidium apetalum*) at Ringgold, Ga., November 24, 1909, a few only were found. *Lepidium virginicum* was a favorite food plant for this insect at Marion, S. C., May 29 to June 14, 1909. It was found rarely on toadflax (*Linaria canadensis*) at Marion, S. C., from May 26 to June 1, 1909, and abundantly on plantain (*Plantago aristata*) at Marion, S. C., June 3, 1909. It was numerous on plantain (*Plantago major*) at Sharpsburg, Md., July 9, 1907, according to Mr. Kelly, and at French Creek, W. Va., November 20, 1908, as reported by Mr. F. E. Brooks in a letter to the Bureau. It was found on water pepper (*Polygonum hydropiperoides*), May 22, 1909, and on another of the knotweeds (*Polygonum muhlenbergii*), October 16, 1909, at Salisbury, N. C., but was not numerous on either of these plants; it was reported also as abundant on purslane (*Portulaca oleracea*) at French Creek, W. Va. It was abundant on poverty weed (*Diodia teres*), at Marion, S. C., May 31 to June 14, 1909, as nearly every plant of this species was infested; it occurred also on cocklebur (*Xanthium canadense*) at Marion, S. C., June 1, 1909.

This insect has been reported and described from Colorado by Cowen on the roots of mint (*Mentha arvensis*) under the name of *Aphis mentha-radicis*.

All the known wild food plants infested by this species are native to the eastern United States except the following: *Amaranthus retroflexus*, *A. spinosus*, and *A. hybridus*, which have been naturalized

from tropical America; and *Chenopodium album*, *Capsella bursa-pastoris*, *Brassica oleracea*, and *B. nigra*, *Polygonum persicaria*, *Rumex crispus*, and *Anthemis cotula*, which are adventitious from Europe or have been naturalized from Europe. They are all annuals except a few which are sometimes biennials.

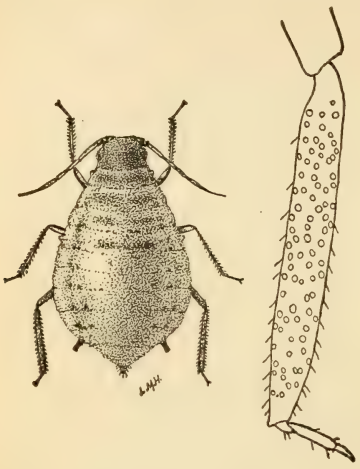

FIG. 56.—The corn root-aphis: Oviparous female and hind tibia. (From Forbes.)

During March and April, 1910, in the vicinity of San Benito, Tex., the writer found this species infesting the roots of the following uncultivated plants: Vervain (*Verbena canadensis*), common nightshade (*Solanum nigrum*), skullcap (*Scutellaria drummondii*), *Teucrium laciniatum*, amaranth (*Amaranthus* sp.), *Selenia* (?) sp., and at Brownsville on the roots of *Iva xanthifolia* (?).

Nothing was found to indicate that it had attacked either corn or cotton, although further investigations will be required to either prove or disprove its occurrence on these or other cultivated plants.

INJURY TO CORN.

Aphis maidi-radicis has been particularly injurious to corn in Maryland, Ohio, Indiana, and Illinois, and has done serious injury to this crop in eastern Pennsylvania, New Jersey, the Virginias, and the Carolinas. In badly infested fields the crop is sometimes almost entirely lost, as shown in the accompanying illustration (Plate V, fig. 1), from a photograph by Mr. W. J. Phillips, of a field in Indiana.

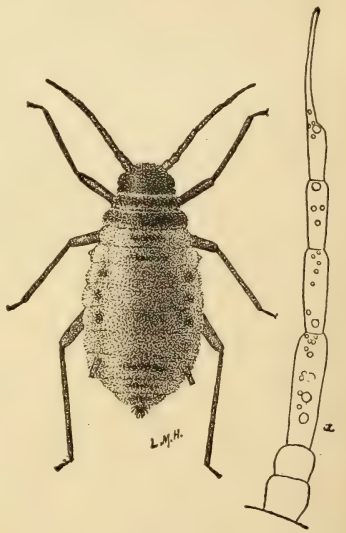

FIG. 57.—The corn root-aphis: Wingless male and antenna. (From Forbes.)

In Illinois its seasonal history, according to Mr. J. J. Davis,[a] is, in brief, as follows: The eggs may be found hatching in the field from April 8 to May 22, and from ten to twenty-two generations may follow. Sexual forms (figs. 56–58) are produced in the latter part of September or in

[a] Loc. cit.

FIG. 1.—DAMAGE TO A FIELD OF CORN IN INDIANA IN 1903 BY THE CORN ROOT-APHIS (APHIS MAIDI-RADICIS). (ORIGINAL.)

FIG. 2.—SAME FIELD A YEAR LATER, SHOWING THE EFFECT OF APPLYING BARNYARD MANURE. (ORIGINAL.)

October, and eggs are laid in October and November. The eggs do not hatch until the following spring. Its seasonal history in other parts of the country does not appear to vary materially from that in Illinois.

RELATION OF ANTS TO THE ROOT-APHIS.

The life of the corn root-aphis in the cornfields is so dependent upon that of the cornfield ant (*Lasius niger* L., var. *americanus* Emery), and vice versa, particularly in the Middle West, that they must be considered together. If it were not for this ant the great damage that is done to corn in this country by the root-aphis would be impossible. The ant is distributed everywhere over North America except in the extreme southern and southwestern portions. It is found in cultivated fields, in pastures, in forests, and along roads. A very complete account of the life history of this ant is given by Doctor Forbes in the Twenty-fifth Report of the State Entomologist of Illinois.

The ants collect the eggs of the aphis in the fall and carry them to their nests, where they are kept during the winter. By bringing these eggs near the surface or carrying them deeper down into their burrows the ants are able to control the hatching of these eggs until weeds spring up upon which the young aphides can feed. As soon as the eggs hatch the young larvæ are transferred to the roots of young weeds such as pigeon grass, smartweed, and ragweed. When the corn begins to come up the colonies of the root-aphis are transferred to the roots of corn. The root-aphis, like all other species in this family, secretes and voids a sweet liquid called honeydew, upon which the ants feed. As this honeydew constitutes the principal food of the ants, the strength of each individual ant colony is dependent upon the number of aphides in its charge.

Although *Lasius niger americanus* is the most important ant that attends *Aphis maidi-radicis* throughout the territory known to be infested by the root-aphis, it is not the only one thus involved. Two other species that are important in this connection are *Lasius flavus* Fab., which has often been observed attending the root-aphis in Maryland, and *Pheidole vinelandica* Forel, which was observed by Mr. J. A. Hyslop attending it at Nathalie, Va., and by Mr. G. G. Ainslie, at Marion, S. C. Among the ants which sometimes attend this species are *Lasius* (*Acanthomyops*) *murphyi* Forel found associated with this species at Arlington, Va., by Mr. Paul Hayhurst, and the following species, which are reported by Doctor Forbes[a] as occasionally attending the root-aphis in Illinois: *Formica schaufussi*

[a] Eighteenth Report of the State Entomologist of Illinois. Trans. Dept. Agr. Ill. for 1893, Springfield, vol. 31, p. 66, 1894.

Mayr, *Lasius interjectus* Mayr, *Myrmica scabrinodis* Nyl., and *Solenopsis debilis* Mayr.

NATURAL CHECKS.

There are no natural checks to the multiplication of the corn root-aphis and its attendant ant except hard, beating rains that are long continued. The thorough soaking of the ground by such rains drowns out many of the aphides, and also the young of the ants.

PREVENTIVE MEASURES.

It happens that over the entire territory infested by the corn root-aphis the best cultural methods for the growing of corn independent of insect injury are just the methods that reduce the numbers of the corn root-aphis and its attendant ant. These methods are crop rotation, maintenance of soil fertility, and early plowing, followed by frequent cultivations.

CROP ROTATION.

The system of rotation that gives the shortest time in corn is the best. In the cotton belt the injury from the root-aphis will be less if cotton and corn are not allowed to follow each other in rotation. Outside the corn belt it makes no difference what the rotation is from the standpoint of root-aphis injury, because no other field crop is injured by this insect. When an old cornfield is sown to some rotation crop, such as one of the small grains, the ants are unable to find food for the aphis except on the roots of weeds, which are soon killed out by the attacks of the aphis, or are smothered by the grain. Large numbers of the aphis will then acquire wings and leave the field. There is some evidence that others are eaten by the ants, but, one way or the other, the field is freed of them.

MAINTENANCE OF SOIL FERTILITY.

The maintenance of soil fertility by the direct application of fertilizers does not lessen the numbers of the aphis, but by furnishing the corn plant with sufficient food it enables it to make a strong growth and mature a crop in spite of the aphis. This benefit is shown in the illustrations (Plate V), from photographs taken by Mr. W. J. Phillips at Richmond, Ind.

EARLY PLOWING, FOLLOWED BY FREQUENT CULTIVATIONS.

In order to reduce the numbers of the root-aphis old cornfields in the Northern States should be plowed in the fall or early spring, and then the ground should be stirred several times before planting, with a corn cultivator or disk harrow. The burrows of the ants infrequently go deeper into the ground than 6 inches, so that if the ground is turned over and thoroughly stirred their nests are broken

up and the contents so scattered that the ants are able to recover only a few of their own eggs and larvæ, and fewer yet of the aphis eggs. This method also prevents the weeds from getting a start, so that there is no food for the young larvæ which hatch from those eggs which the ants are able to preserve. This is a good treatment for land that is to be planted to corn throughout the section of country where the root-aphis is found, but more especially in the northern part of the infested territory.

In the more southern part of the range of this insect winter plowing may be practiced with good results wherever the land is sufficiently level so that it will not wash badly. Winter plowing breaks up the ants' nests and scatters the contents of these nests at a time when the ants are least able, because of the cold wet weather and shortness of the food supply, to recover from the injury.

One example of the effects of winter plowing that came under the observation of the Bureau of Entomology was as follows: Mr. John Bowie, at Annapolis Junction, Md., plowed the major portion of a 60-acre field in the winter of 1905–6, leaving unplowed a small strip in the middle, which he finished in the spring. Prof. F. M. Webster visited this field July 28, 1906, and found that owing to injuries by the root-aphis the spring-plowed portion of the field would almost fail to produce a crop, while the winter-plowed portion gave promise of an unusual yield. On the spring-plowed area much of the corn was missing, while many of the surviving stalks were dwarfed. By these signs it was easy to determine at a glance the dividing line between the two areas. On September 22, 1906, just after the corn was cut and shocked, this field was visited by Mr. C. N. Ainslie, and he, too, was able clearly to separate the two areas, being guided only by the appearance of the stubble.

In the southern part of its range the corn root-aphis is able to spend the entire summer on its wild food plants, and these wild plants are especially infested in the late summer and early fall. If, then, these weeds are destroyed by thorough cultivation, the root-aphis is encouraged to leave the fields. In the fall eggs are laid on the roots of late scrub corn which was not harvested and on the roots of weeds such as Ambrosia and pigweed. Fall plowing as soon as possible after the crop is harvested will prevent these eggs from being laid in the field. The land may then be put into some cover crop.

REPELLENTS.

The method of combating the root-aphis by direct application of repellents to the seeds was investigated by Doctor Forbes and reported in the Twenty-fifth Report of the State Entomologist of Illinois. Many substances were experimented with, such as oil of lemon, oil of cloves, kerosene, and carbolic acid. Of these, oil of

lemon appears to be most promising. A solution of the oil in alcohol—1 part of the oil to 9 parts of ordinary commercial alcohol—is used. About 3 ounces of this mixture is used to a gallon of corn. It should be stirred thoroughly till all the seed is moistened. This treatment costs only 10 cents an acre for the materials, and appears to be very effective.

INJURY TO COTTON.

A form of *Aphis maidi-radicis* was very injurious to young cotton on the light sandy soil of the eastern parts of North Carolina and South Carolina throughout the seasons from 1907 to 1909. During this time it was the most injurious enemy of cotton in that region. In this form, which is apparently the same as that found on corn at Duncan, Okla., by Mr. T. D. Urbahns, of this Bureau, the spots on the back of the apterous vivipara are larger and darker than they are on the typical *Aphis maidi-radicis* as found on corn roots in Illinois. The third antennal segment has two or three circular sensoria which are not present in the Illinois variety. Although this insect was first brought to the attention of entomologists as a cotton pest in 1907, some of the cotton planters in North Carolina have known of it for upward of twenty years.

It attacks cotton just as soon as the young plants appear above ground and is usually first noticed when the plants are about 2 inches high. The cotton plants in certain areas will turn red and die, shriveling up so that they can be seen with difficulty. In one field, examined May 28, 1909, at Marion, S. C., by Mr. G. G. Ainslie, fully 90 per cent of the cotton was infested. As a rule most of the aphides observed were in a cluster on the main stem just below the surface of the ground, but a few could be found anywhere on the roots, even to the tips of the longest rootlets. Mr. Ainslie found as many as 200 insects, in all stages, on one plant.

As far as the study of this insect has gone it appears that the root-aphis infests cotton only while the plants are young and tender, and leaves as soon as the roots begin to get hard and woody; or they remain only on the fibrous rootlets deep down in the soil where they are unable to do much damage. They leave the plants as winged migrants or are transferred by the ants to some of the numerous wild food plants of this species.

The ravages of this insect in the cotton fields can be largely prevented by proper rotation and better cultivation. Most of the planters reported that the insect was less injurious where cotton was grown after cotton. This is because the cotton fields are usually well cultivated, so that when the root-aphides leave the cotton plants they leave the cotton fields, and their eggs are not left in the fields in the fall.

Many of the planters report that cotton is more seriously injured when it is planted after corn. This is because the root-aphis can feed on the roots of corn all summer and also because the cornfields are not kept clear of the wild food plants of this insect. For this reason the aphides can find an abundant food supply in the cornfields all summer. In cornfields as far south as Salisbury, N. C., the eggs of this aphis are laid on the roots of late replanted or scrub corn which was left uncut, or more often, perhaps, on the roots of its wild food plants. These eggs are then taken into the burrows of the ants and cared for by them during the winter. When these eggs hatch in the spring, the young larvæ are placed by the ants on the roots of cotton or corn, if these crops are up; if not, they are placed on weed roots and live there for a while, and most of them are transferred to the roots of corn and cotton as soon as these plants become available.

If corn is to be followed by cotton, it will be best to plow the land as early as possible in the fall and to sow to a cover crop later. This will prevent the eggs of the root-aphis from being laid in the field, while the plowing and cultivation will break up the nests of the ants and prevent them from caring for the eggs that are laid. The borders of the field should be kept as clear of weeds as possible.

INJURY TO ASTERS.

The first record we have found regarding the injury of a root-aphis to the Chinese or German aster is in an article on "The culture of the aster," by Edward S. Rand,[a] in which he says:

> The earth should not be sandy, as in such soil they are very subject to the attacks of a root-aphis, which always proves fatal to the plant.

And again:

> For the root-aphis which troubles the plant in sandy soils we know of no remedy but to dig up the affected plant and destroy the insect.

From this it appears that the root-aphis was well known as a serious enemy of the aster in New England as early as 1858, or only about thirteen years after the China aster became numerous there. A later record is found in the Practical Farmer for 1875, an extract of which is given in the Horticulturist and Journal of Rural Art and Taste,[b] where mention is made of the "dusty louse" which "is found at the roots of German asters in hot, dry weather." Watering the asters heavily is mentioned as a remedy.

The first record in the files of the Bureau of Entomology in regard to this pest on asters is an inquiry from Washington, D. C., in July, 1899. Since then inquiries have come from the following States:

[a] Trans. Mass. Hort. Soc. f. 1858, pp. 26, 27.

[b] Horticulturist and Journal of Rural Art and Taste, vol. 30, p. 366, 1875.

Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, West Virginia, Ohio, and Illinois.

Mr. J. A. Kreutzberg, writing from Chicago, Ill., September 9, 1908, says:

> From 500 to 1,000 plants grown from seed early every year in the hotbed, and in due time transplanted in the open ground, rarely more than one-third survive and pull through to full growth and beauty. The trouble appears to be a small green louse which looks like the aphis which infests the rose bushes, lodging in the roots, forming large colonies in them, and working their way up in the plants to the surface of the ground. Some of the plants are blighted as soon as they are set in the open ground, some later, and some when the plants are in full bloom. The moment that the plants are attacked by these parasites they show it by turning yellow and wilting down to the ground.

In a later letter, September 15, 1908, he says:

> I this morning pulled up three aster plants which were in full bloom, yet showed the taint of the ravages of the aphis, which apparently did not attack the plant until quite recently. In looking over my aster field this morning I find that nearly every plant is affected, which was conclusive proof to me that these little pests begin their attack during all stages of growth of the plants. Some are attacked immediately after transplanting to the open ground, others a little later on, and some that seem to have strength enough to pull through and are in bloom are attacked after the bushes are loaded with flowers. These three plants that I pulled today were loaded with the insects, but of a different color than I have found them heretofore, but apparently the same genus.

The other reports are much the same. The aphides apparently attack the asters as soon as they are set out in the open and feed on them till the sexual forms appear and the eggs are laid in the fall. The correspondents often report that the aphides are attended by ants, but only one species has been taken and identified. *Lasius alienus* Först was sent to the Bureau by Mr. C. R. Cranston from Providence, R. I., with the following information:

> Just as the [aster] buds begin to form, the leaves all turn yellow and the plant never blooms. On pulling some up I found that ants had taken green plant lice under ground to suck the sap from the roots.

It should be easy to keep the asters free from this pest if the following precautions are taken: Choose for the aster bed ground that has not grown asters or corn for the past year. Free this ground from the wild food plants of this species some time during August. Then, if there is no crop on the ground, it may be cultivated, covered with manure, and left till next spring. The only way for the aphis to reach the plants on this ground would be for the winged migrants to fly to the plants and then be captured and taken to the roots by ants. It is extremely improbable that those reaching the plants in this way could increase in numbers fast enough to do serious injury. In fact, if the asters are planted in ground which has not grown asters or corn the past year, and which is not located near a field of

corn or an infested aster bed, they will not be troubled with this pest, provided the wild food plants of the pest were removed from the vicinity of the bed as mentioned above.

OTHER CULTIVATED FOOD PLANTS.

A root-aphis was reported, in October, 1908, by the M. Crawford Company, of Cuyahoga Falls, Ohio, to be injuring strawberry plants in a field which had been in corn the year before. This aphis was identified by Mr. Theo. Pergande as *Aphis maidi-radicis*.

Mr. C. H. Popenoe, of this Bureau, collected it from the roots of cabbage at Doncaster, Md., July 24, 1907. These specimens were also identified by Mr. Pergande as *Aphis maidi-radicis*.

These aphides were found to be injurious to pumpkin and watermelon at French Creek, W. Va., in July, 1908, as reported in a letter from Mr. F. E. Brooks:

> I have found the aphis on roots of watermelon and pumpkin growing where an old sod of orchard grass was plowed down last spring. The cucurbits grew about 100 yards from a cornfield that was infested last season.

What is supposed to have been *Aphis maidi-radicis* was reported from Dover, Del., to be injuring French artichoke. Mr. Theophile Berneau, of Dover, in a letter to the Bureau of Entomology, August 25, 1908, says:

> I am cultivating French artichoke, *Cynara scolymus*, and have some trouble with minute insects which settle on the roots and suck the sap, to the great detriment of the plant.

Mr. Berneau reported that these insects were accompanied by a great number of ants.

This species was reported as injurious to dahlia at Longmeadow, Mass., and at Springfield, Mass., in 1906. In a letter from Springfield dated June 4, 1906, Mrs. T. G. Forster says:

> I have set out a few dahlia bulbs and find they will not grow. To-day on unearthing some of them I find the roots and also the sprouts—the part inside the ground—covered with small white lice which seem to eat the small new roots as they start to grow. Have had some trouble with them before.

DESCRIPTION AND SYNONYMY.

There is some question as to whether, in our study of this insect, we are dealing with one or with more than one species. There is a form which feeds on the fleabanes (Erigeron) and on wild asters, described by Cyrus Thomas in 1879 as *Aphis middletoni*. This is probably a distinct species, although further study may show that it is the same as *Aphis maidi-radicis*, in which case both forms would be known as *Aphis middletoni* Thos.

Specimens found on the roots of corn, in Oklahoma, by Mr. T. D. Urbahns, of this Bureau, and on cotton, in South Carolina, by Mr. G.

G. Ainslie, at that time a special field agent of this Bureau, are about the size of the typical *Aphis maidi-radicis* but they have circular sensoria—usually about three on the third segment of the antenna—and have larger and darker markings on the thorax and abdomen than has the typical *Aphis maidi-radicis*. This form is without much question only a variety of the true *Aphis maidi-radicis*. It seems best at the present time to recognize two species, viz, *Aphis middletoni* Thos., feeding on plants of the genera Aster and Erigeron, and *Aphis maidi-radicis* Forbes, which feeds on corn, cotton, and many wild plants.

FIG. 58.—The corn root-aphis: Winged male, greatly enlarged, and antenna, highly magnified. (Original.)

Mr. J. H. Cowen describes an aphis under the name of *Aphis menthæ-radicis* which was taken on *Mentha canadensis* at Hotchkiss, Colo., July 14.[a] This is the same as the form on the roots of corn, and must therefore be considered a synonym of *Aphis maidi-radicis*. In a recent letter Prof. C. P. Gillette, entomologist of the experiment station, says:

I have compared the type specimens with the slide (*Aphis maidi-radicis*) you sent, and am a little in doubt as to whether there is sufficient difference to consider the lice from the mint as a different species. I hardly think they are. It also seems that Mr. Cowen's *armoracea* is also in all probability *maidi-radicis*, but before finally deciding this matter I should like to compare the

[a] Description published in "A Preliminary List of the Hemiptera of Colorado." By C. P. Gillette and Carl F. Baker. Bul. 31, Colo. Agr. Exp. Sta., p. 121, 1895.

living lice from the different plants. *Armoracea* we have found very abundant here on horse-radish.

As very complete descriptions of the different forms of *Aphis maidi-radicis* have been published, no descriptions are given in this paper except that of the winged male, which has not been before observed or described. Two of these males appeared in the vials in which *Aphis maidi-radicis* from the roots of *Ambrosia artemisiifolia* were being reared on corn, and one in the vial of Aphis from *Leptochloa filiformis*. Two of these were used in experiments; the other was preserved and is described below.

Winged ♂ (fig. 58).—Head, thorax, eyes, and appendages black. Abdomen green, with dark transverse bars on the dorsal side of the 5th, 6th, and 7th somites. The beak reaches the metathorax. The antennæ reach the caudal end of the second abdominal somite. The circular sensoria are arranged on the antennæ as follows: 24 on the third, 12 on the fourth, 7 on the fifth, 4 on the sixth. Length of body, 1.50 mm.; length of wing, 1.75 mm.; length of cornicle, 0.10 mm. (Measurements made from specimen mounted in balsam.)

In 1856 Doctor Fitch described the corn leaf-aphis (*Aphis maidis*), and up to 1891, when it was described by Doctor Forbes, what is now known as *Aphis maidi-radicis* was supposed to be only a root form of that found on the leaves. No one, however, has been able to trace a sexual relationship between the two. Although the sexual forms of *A. maidis* have never been observed, it does not seem possible that such a relationship as was previously supposed can really exist. Besides, while, as shown by map on page 114, *Aphis maidi-radicis* is confined to the country east of the one hundredth meridian, *Aphis maidis* occurs from Maine to southern California.

THE ERIGERON ROOT-APHIS.

(*Aphis middletoni* Thos.)

The species *Aphis middletoni* Thos. is considered here because it has usually been identified as *Aphis maidi-radicis* in publications; and because it is impossible to study one of these forms on various food plants over a wide extent of country without studying the other.

So far as is now known *Aphis middletoni* infests normally plants of the genera Aster and Erigeron, usually in very large colonies at the crown of the plant just below the surface of the ground or on the large roots. The only cultivated plants it has been known to attack are *Cosmos bipinnatus* and the China or German asters (*Callistephus hortensis*), and possibly also dahlias and French artichoke (*Cynara scolymus*).

Aphis middletoni was first described by Cyrus Thomas, in 1879, in the Eighth Report of the State Entomologist of Illinois. Since then it has been referred to in literature only in food-plant lists. It has

generally been confused with the corn root-aphis, and when found on any other plant except Erigeron it has usually been identified as *Aphis maidi-radicis*. It is much smaller than the latter species and is usually more heavily powdered with a waxy material. Its cornicles are about one-half the length of those of the corn root-aphis. The third antennal segment in the apterous, viviparous female has a group of 5 or more circular sensoria, and there is also a group of circular sensoria on the fourth, and sometimes also on the fifth segment. In the typical *Aphis maidi-radicis* these circular sensoria are not present. The winged vivipara are smaller than those of *Aphis maidi-radicis*, have shorter cornicles, and circular sensoria on the third,

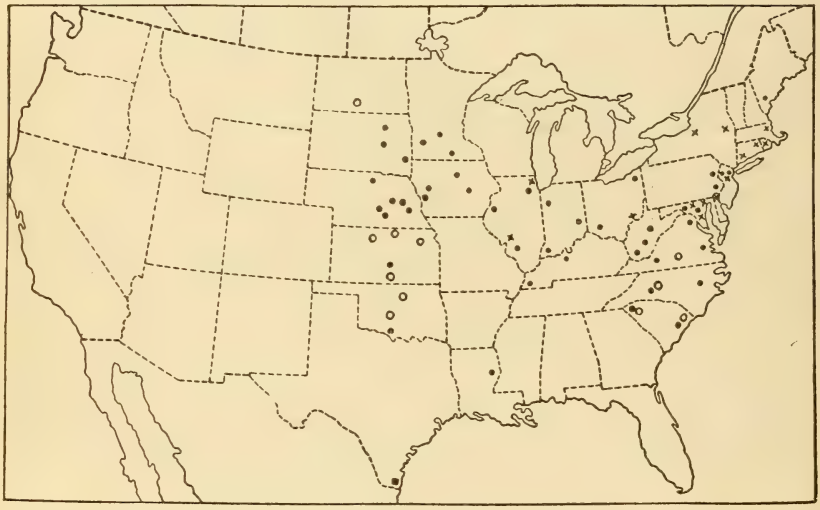

FIG. 59.—Map showing distribution of *Aphis maidi-radicis* and *Aphis middletoni* in the United States. From the records of the Bureau of Entomology. ● Localities in which *Aphis maidi-radicis* has been found or reported on the roots of corn. × Localities in which *Aphis maidi-radicis* has been reported injurious to asters. ▣ Locality where *Aphis maidi-radicis* was found on uncultivated plants only. ○ Localities in which *Aphis middletoni* has been collected.

fourth, and fifth antennal segments, while *Aphis maidi-radicis* has these sensoria only on the third segment. The same differences are found in the oviparous females.

This species appears to have been a native of the Great Plains, but is now distributed widely over the territory east of the Rocky Mountains, as is shown in figure 59.

UNCULTIVATED FOOD PLANTS.

Aphis middletoni has been found on the following wild food plants: On *Erigeron canadensis*, mostly in the Northwest; on *Erigeron ramosus*, in the Carolinas; on the roots of *Aster subulatus*, at Salisbury, N. C., from May 22 until September 22, 1909, and on

Aster ericoides, from September 18 until November 15, 1909. Sexual forms were found on this plant at Salisbury, N. C., November 15, 1909, and at Rockmart, Ga., November 23, 1909. Cosmos (*Cosmos bipinnatus*), which had escaped from cultivation and was growing wild along the roadside at Salisbury, was also found infested by this aphis in October, and on November 5 sexual forms were present on the roots of the plant.

CULTIVATED FOOD PLANTS.

Specimens of an aphis which attacked the roots of China asters (*Callistephus hortensis*), received from Dr. E. P. Felt, of Albany, N. Y., apparently belong to this species, but specimens collected from the roots of cultivated aster at Chicago by Mr. J. J. Davis are without any doubt *Aphis maidi-radicis*. It is yet an open question to which species the insect which has been attacking cultivated asters in the North Atlantic and New England States belongs. The species which attacks dahlias and French artichokes (*Cynara scolymus*) belongs to one of these two, but to which one can only be settled by obtaining more material. *Cosmos bipinnatus* was found infested by *Aphis middletoni* October 6, 1909, at Salisbury, N. C. The writer has found no record in the American or foreign literature of an aphis infesting the roots of dahlia, artichoke, or cosmos. *Cosmos bipinnatus*, which grows wild in Mexico, may have been one of the original food plants of this species.

ATTENDANT ANTS.

The Erigeron root-aphis is attended by a larger number of ant species than is *Aphis maidi-radicis*. It is seldom found associated with *Lasius niger* L. var. *americanus* Emery, which commonly attends the corn root-aphis, but is ordinarily found attended by a medium-sized black ant, *Cremastogaster lineolata* Say, which on the other hand seldom attends the corn root-aphis.

Lasius niger americanus was observed associated with this species by Mr. J. A. Hyslop at Nathalie, Va., July 9, 1908, and by the writer at Salisbury, N. C., on *Cosmos bipinnatus* November 5, 1909, and on *Aster ericoides* November 15, 1909.

Cremastogaster lineolata was observed associated with this root-aphis by the writer at Salisbury, N. C.; by Mr. G. G. Ainslie at Clemson College, S. C., and by Mr. Paul Hayhurst at Ponca City, Okla., Newkirk, Okla., and Wellington, Kans. At Winfield, Kans., it was found by Mr. Hayhurst associated with the varieties of this ant known as *opaca* and *clara*. This ant and aphis were also found associated at Wellington, Kans., by Mr. E. O. G. Kelly.

The following ants were found associated with this species on the roots of *Erigeron canadensis:* By Mr. Hayhurst—*Pheidole* sp. at Arkansas City, Kans., *Solenopsis geminata* Fab. and *Dorymyrmex pyramicus* Roger at Kingfisher, Okla., and *Iridomyrmex analis* Ern. at Newkirk, Okla.; by Mr. Kelly—*Solenopsis molesta* Say, *Lasius interjectus* Mayr, *Monomorium minutum* Mayr var. *minimum* Buckley, and *Ponera coarctata* Latr. var. *pennsylvanica* Buckley, at Wellington, Kans.; by Mr. G. G. Ainslie—*Pheidole vinelandica* Mayr at Marion, S. C. The ant *Prenolepis imparis* Say was found by the writer associated with this root-aphis on *Aster ericoides* at Rockmart, Ga.

LABORATORY AND FIELD EXPERIMENTS.

Many laboratory experiments were carried on by the writer at Salisbury, N. C., to determine the adaptability of *Aphis middletoni* to other food plants. Wingless females were taken from the roots of *Erigeron ramosus* and transferred to sprouting corn and to sprouting cotton in vials, and although this experiment was tried several times, using several females each time, it was unsuccessful. A number of experiments were tried, using the females from the roots of *Aster subulatus.* These also were unsuccessful, with the following single exception: Females removed from the roots of *Aster subulatus* to sprouting cotton, August 30, produced young which succeeded in supporting themselves on the cotton. Several generations were produced, but the aphides never acquired the characters of *Aphis maidiradicis.* Oviparous females were produced October 9 and others were produced later, the experiment being closed November 22.

Mr. Kelly carried on similar experiments at Wellington, Kans., in 1908, which were more successful. His experiments, in brief, are as follows:

Experiment D.—A stem-mother was removed from the roots of a young Erigeron plant May 9 and placed on a young Erigeron plant in a vial. The young which she produced were placed on sprouting corn in vials.

Experiment D^1.—One young born May 10(?) became adult May 19 and produced 45 young between May 20 and June 7.

Experiment F^1.—One larva removed from cage D May 12, matured May 22(?), and produced 35 young from May 22 to June 2.

Experiment F^2.—One larva from cage F^1, born May 22, matured May 30, and produced 32 young from May 30 to June 7.

Experiment F^3.—Larvæ removed from the above experiment May 30 did not mature on corn.

Mr. G. G. Ainslie carried on similar experiments in 1908 at Clemson College, S. C. The most successful experiment was as follows:

A few aphides from the roots of *Erigeron canadensis* were placed on sprouting corn in a vial, October 30; by November 9 four young

had been produced and on November 20 one wingless viviparous female remained alive. The experiment was closed November 20.

These experiments show that the Erigeron aphis can be transferred to corn or cotton roots and will live on these plants. It seems to take to these plants more readily early in the spring or late in the summer, when a migration from a wild food plant is about to take place. The fact that, when grown on corn, this aphis still retains its distinctive characters, instead of acquiring the characters of *Aphis maidi-radicis*, goes to show that these two are distinct species.

Mr. Hyslop and Mr. Kelly carried on experiments of a different nature for the purpose of determining these points.

Mr. J. A. Hyslop, on July 29, 1908, found specimens of *Erigeron canadensis* in the grounds of the U. S. Department of Agriculture at Washington, D. C., badly infested with this aphis. Near these plants he planted corn, watermelon, and cucumber seeds. On September 23 he pulled all of these plants. The Erigeron plants were infested, but no aphides were found on the other plants, even though the roots intermingled in many instances.

On August 11 Messrs. Kelly and Urbahns, at Wellington, Kans., planted corn, squash, cucumber, and watermelon near an infested Erigeron plant. These plants were watched till October 12, during which time the aphides continued on the Erigeron, but were found at no time on the other plants.

Mr. Kelly, at Wellington, Kans., on August 26, 1908, planted corn, watermelon, cucumber, squash, and pumpkin seeds near infested plants of *Erigeron canadensis*. He examined these plants, September 29, but found aphides only on the Erigeron, although the roots of the plants often intermingled.

These experiments show that under natural conditions in the field this aphis will not change from the Erigeron to the corn. What it would do if forced to leave the Erigeron is uncertain, but we have no evidence thus far that it can live for any very long time on the roots of corn.

While making a trip through the Northwest, in June, 1908, for the purpose of studying the insects affecting cereal and forage crops, Mr. Kelly made a careful study of *Aphis maidi-radicis* and *A. middletoni*. At Hastings, Kearney, Columbus, and Fremont, Nebr., and at Missouri Valley and Marshalltown, Iowa, *Aphis maidi-radicis* was common on the roots of corn; but although *Erigeron canadensis* was plentiful, the roots sometimes intermingling with the roots of corn, there were no aphides on the roots of Erigeron. At Bismarck, N. Dak., and Norton and Phillipsburg, Kans., the Erigeron plants were common and had aphides on their roots, but there were no aphides on the roots of corn.

At many of the towns visited neither species was found, although their food plants were plentiful. If these two forms were considered to be one species these results would be very difficult to explain.

At Salisbury, N. C., a colony of these aphides on *Aster subulatus* was found parasitized by a species of the hymenopterous genus Lysiphlebus. This colony was at the crown of the plant near the surface of the ground.

U. S. D. A., B. E. Bul. 85, Part VII. C. F. I. I., October 7, 1910.

PAPERS ON CEREAL AND FORAGE INSECTS.

THE SMOKY CRANE-FLY.

(*Tipula infuscata* Loew.)

By James A. Hyslop,
Agent and Expert.

INTRODUCTION.

The maggots or larvæ of the Tipulidæ are known in the several parts of this country by many local names, among which, perhaps, the most generally applied are "meadow-maggots," "leather-jackets," "grubs," and "cutworms." The last name has proved most unfortunate, leading to great confusion in Departmental and station correspondence, and has arisen from a mistaken, though very prevalent, impression among farmers that these larvæ are the same as the true cutworms, and that in late spring when the weather conditions are favorable the so-called "cutworms" come to the surface of the ground where they "burst" from exposure to the sun's rays. The larvæ, for it is in the larval stage of development exclusively that these insects are of economic importance to the farmer, are really the young of several species of crane-flies—also known as "gallinippers," "giant mosquitoes," and "daddy-long-legs." The last name, however, is sometimes applied to the eight-legged and wingless harvest spiders (Phalangidæ).

A comprehensive economic treatment of this family of insects, as such, is impossible at the present time, owing to the necessarily fragmentary condition of our knowledge of the early stages of most of the species and the great diversity of habits exhibited by those which have been studied. In mode of living they range from the aquatic

Note.—The author wishes to acknowledge the assistance, received in preparing this paper, of Messrs. Nathan Banks, Frederick Knab, and D. W. Coquillett, who critically reviewed the technical descriptions, and of Mr. R. E. Snodgrass, who prepared the anatomical drawings of the larval head. The other illustrations were prepared by Mr. J. F. Strauss and the author.

forms such as *Limnophila luteipennis* O. S., *Helobia punctipennis* Meig., *Erioptera graphica* O. S. (C. A. Hart, 1895), and *Tipula abdominalis* Say, through the semiaquatic forms, of which *Holorusia rubiginosa* Loew (V. L. Kellogg, 1901) is an example, to the distinctly terrestrial forms among which are several species of Tipula and most of the species of *Pachyrhina*, so far as the latter have been studied. In seasonal development they range from *Tipula virgo* O. S., *T. eluta* Loew, *Pachyrhina ferruginea* Fab. and *P. macrocera* Say, which are flying about in March and April; through *Tipula spernax* O. S. and *T. angustipennis* Loew, which appear in May; most of the species of *Pachyrhina*, so far as studied, *Tipula fuliginosa* Say, *T. trivittata* Say, *T. tephrocephala* Loew, *T. bicornis* Loew, and *T. graphica* Doane, abroad in early June; *Tipula grata* Loew, *T. angulata* Loew, and *T. tricolor* Fab., in July; *Pachyrhina sodalis* Loew, a probable second brood of *P. ferruginea* Fab., *Tipula hebes* Loew, *T. abdominalis* Say, *T. costalis* Say, *T. macrolabis* Loew, *T. valida* Loew, and the second brood of *T. bicornis* Loew, in August and September; and last to *Tipula flavicans* Fab. and *T. infuscata* Loew, which appear in October.

Among the observations on these insects in relation to agriculture in the United States might be mentioned an article by Dr. T. W. Harris (1854), in which he records receiving a bottle of tipulid larvæ with a letter stating that they were found alive in great numbers on the snow in March. Dr. C. V. Riley (1867) briefly mentions them as of economic importance. Dr. B. D. Walsh (1869) refers to a letter from a farmer at Mexico, Mo., who complains of these larvæ in his garden and who notes that they stand freezing with impunity. Doctor Riley (1870) published a letter from a correspondent at Meadville, Pa., in which he records finding these larvæ in great numbers under mulch hay. Dr. S. A. Forbes (1888) reports a very general and serious outbreak of tipulids (*Tipula bicornis* Loew) in grass and clover meadows throughout southern and central Illinois, many pastures and hayfields being almost completely ruined. He also published a letter from Doctor Riley (1888) in which the latter reports a very similar outbreak in California in 1874. In an unsigned article in the Pacific Rural Press for March 29, 1889, record is made of an outbreak in Healdsburg, Cal., specimens having been received at the state agricultural experiment station with the note that they were completely stripping the wheat fields. Prof. F. M. Webster (1892) records a bad outbreak of tipulids (*Tipula bicornis*) in Anderson, Ind., in 1888, the larvæ attacking clover. He also records an attack of *Pachyrhina* sp. on young wheat near Farmersburg, Ind.

On April 2, 1908, a number of tipulid larvæ were received at this office from Mount Vernon, Ind., with the note that they were very numerous in hay meadows in that locality. Mr. R. W. Doane, in a

letter to this office, records a very serious outbreak of Tipulidæ (*Tipula simplex* Doane) in central California during the season of 1907, and states that thousands of acres of wheat and grass lands and clover fields were absolutely stripped of verdure.

In Europe *Tipula oleracea* L. and other species have long been recognized as important pests.

DESCRIPTION.

THE ADULT.

The species was originally described by Loew (1863) from a single female specimen. The original description, translated by the author, is as follows:

Gray, thoracic stripes brownish gray, darkly margined, median stripe imperfectly divided; abdomen darkly testaceous, median line clouded, posterior margin of each segment, all of the last segments, and the base of the ovipositor brownish gray, opaque; wings uniformly faintly clouded, the apex of the same color, costal cell and stigma clouded. Length of body 7½ lines, length of wings from 7½ to 7¾ lines. Head gray, rostrum reddish brown, becoming gray above, palpi dark yellow, apex nearly black. First antennal segment reddish brown, grayish, second segment red, flagellum black, basal segment red. Dorsum of thorax gray, stripes brownish gray and more darkly margined, median stripe imperfectly divided. Pleura whitish gray. Abdomen dark testaceous, posterior margin of each segment, all of last segments, lateral margin, and base of ovipositor grayish brown, opaque, narrow median stripe fuscus. Lamellæ of the ovipositor rufotestaceous, the upper ones pointed and slightly curved inward. Wings faintly clouded, apex of the same color, first basal cell and stigma brown.

NOTE.—Very close to *Tipula helva*, except that the whole body is darker and the wings are more evenly colored.

In addition to the original description the author desires to add the following:

Female (fig. 60).—Ovipositor consisting of 4 external, brown, chitinous plates and a semichitinous yellow lingulaform appendage. Upper plates one-third longer than lower ones, sword-shaped, slightly flexed ventrad; on inner surface of fused upper plates a hemispherical, bilobed, membranous cushion closely set with fine hairs; lower plates truncate and nearly concealed by upper plates when insect is at rest; inner surface of each lower plate with several hairs; lingulaform appendage triangularly grooved dorsally, and quite hairy. Length of body, 18 mm.; wing, 15.5 mm. (measurements made from dried specimens).

Male (fig. 61).—General color of head and thorax brownish gray, abdomen and legs yellow, eyes black, rostrum yellowish brown below and pale yellowish gray above, palpi clouded; scape of antennæ yellowish gray, distal half of joint 3 and remaining joints brown. Thorax marked with a light-gray median line which is distinct anteriorly but fades out about half way to the V-shaped suture; a light-gray margin around the anterior border of the mesothorax, widening to triangular patches at the spiracles, and 2 longitudinal lines parallel to the median line, arising at the apices of the triangular patches and extending backward to the V-shaped suture; pleura and coxæ whitish gray; femora light yellow, densely clothed with short black hairs; tibia and tarsi darker and clothed with short black hairs. Abdomen with narrow ventral,

a narrow lateral, and a broad dorsal brown stripe. Wings evenly clouded, the veins, marginal cell, and stigma brown. Hypopygium globular, though not conspicuously broader than preceding segments; pleural suture distinct at its distal end, although obliterated proximally; middle apical appendages each bearing a stout black hook which curves inward, upward, and forward; upper apical appendages consisting of sparsely hairy, quadrate, yellow flaps which are rolled upward, inward, and then downward; lower apical appendages

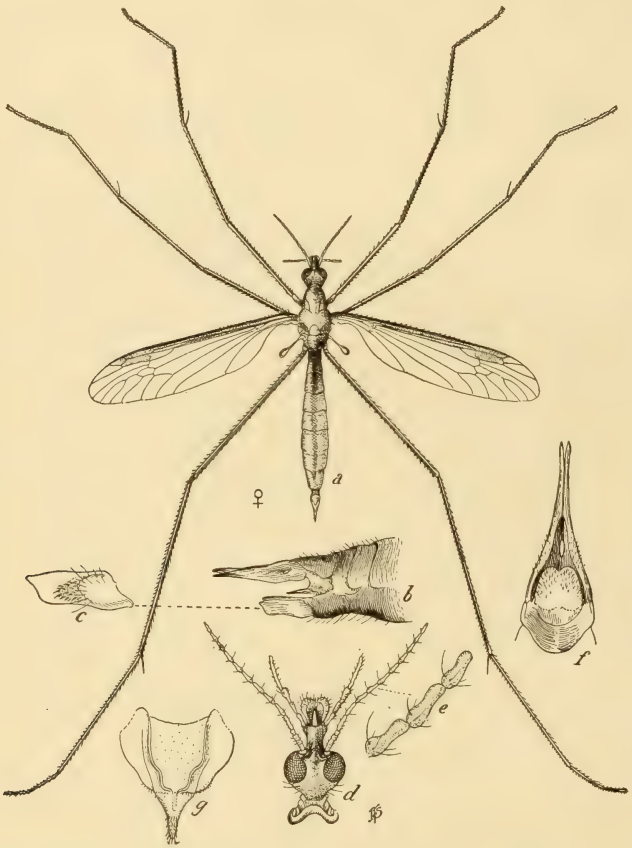

FIG. 60.—The crane-fly (*Tipula infuscata*): *a*, Adult female; *b*, ovipositor, lateral aspect; *c*, lower genital plate, inside surface; *d*, head, dorsal aspect; *e*, antennal joints; *f*, ovipositor, ventral aspect, with lower plates removed; *g*, lengulaform appendage of same. About natural size. (Original.)

consisting of heavy, convex, triangular pieces bearing several hairs. A small semichitinous flap is situated directly above the ventral carina. Two prominent blunt teeth arm the dorsum of the ninth segment. Length of body, 13.5 mm.; wing, 14 mm. (measurements made from dried specimens).

THE EGG.

Egg (fig. 62) shiny black, elongate oval, one end being slightly conoidal; a distinct round pit on one side near conoid end. Length, 884μ; width, 245μ.

THE LARVA.

Larva (fig. 63, *a*) filiform, 19 mm. in length and 3 mm. in diameter at its widest point when fully extended. General color dirty yellowish brown, dark-

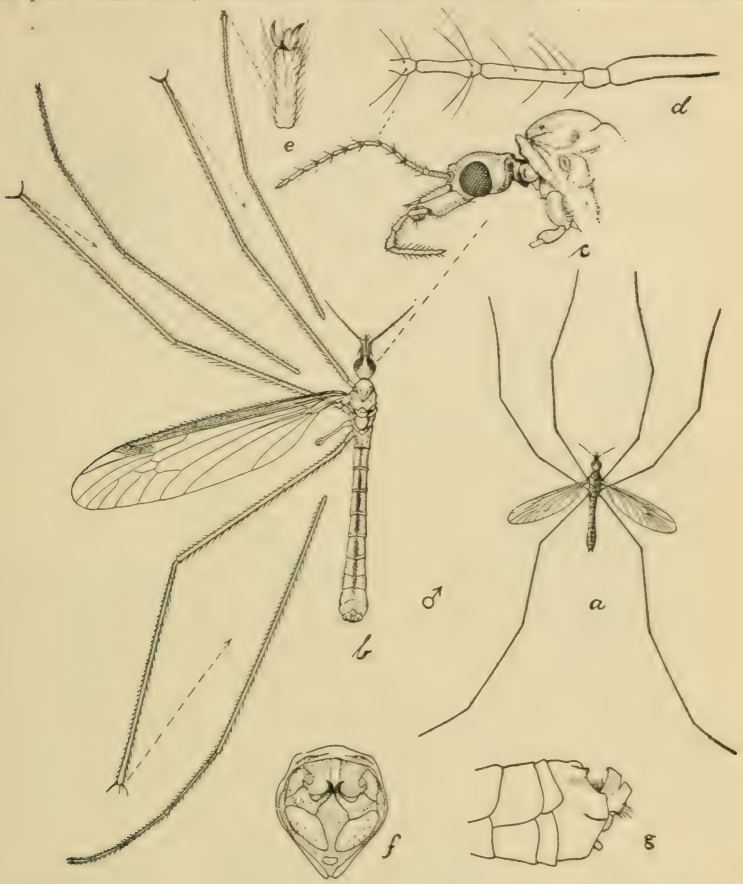

FIG. 61.—The smoky crane-fly: *a*, *b*, Adult male; *c*, thorax and head, lateral aspect; *d*, antennal joints I–IV; *e*, tarsal joint and ungues; *f*, pygidial segments, terminal aspect; *g*, end of abdomen, lateral aspect. *a*, natural size; *b*, enlarged; *c–g*, much enlarged. (Original.)

ening to almost black at the extremities. Body composed of 13 segments, the head being about two-thirds incased in the first and entirely retractile within the first two segments. Posterior segment (fig. 63, *k*) terminated by 4 blunt, radially arranged tubercles, between which are 2 large black spiracles; when contracted the 4 tubercles completely conceal the spiracles; on ventral surface of this segment are 4 large and 2 smaller radially arranged pseudopods, posterior to which is the anus (fig. 63, *i*).

FIG. 62.—The smoky crane-fly: Eggs. Highly magnified. (Original.)

Head (fig. 63, *c*, *e*) partly chitinized, 2.1 mm. in length and 1.4 mm. in width. Genal region extending backward from the mandibles and maxillæ as two strongly convex plates, deeply pigmented on their anterior half and fading out to transparent chitin on their posterior margins. These plates are widely separated postero-ventrally, to form the pharyngeal foramen; antero-ventrally they are continuous with the mentum. Dorsally they appear to

approximate each other, owing to 2 posteriorly directed, narrow lobes, leaving between them a narrow, dorsal, median, semitransparent area which widens an-

FIG. 63.—The smoky crane-fly: *a*, Larva, left side; *b*, clypeo-labral part of head, dorsal aspect; *c*, ventral aspect of head, showing also position of front edge of prothorax; *d*, maxilla; *e*, dorsal view of head; *f*, left mandible and its muscle apodemes, ventral aspect; *g*, left mandible, dorsal aspect; *h*, mental lobes of ventral wall of head; *i*, anal segment, terminal aspect; *k*, same, dorsal aspect. *a*, Enlarged; *b–k*, more enlarged. (Original.)

teriorly to receive the fused frons, clypeus, and labrum. Postero-ventrally the gular region seems to be separated from the occipital region by a transparent

area extending from the pharyngeal foramen dorsally and posteriorly about one-third of the distance to the vertex. Mentum (fig. 63, *h*) terminated by a median blunt lobe supported on each side by a smaller lobe and two partly fused lobes; a nonchitinized, transparent area extends from the pharyngeal foramen into the apex of this organ, this area separated from the foramen proper by a pair of posteriorly directed, blunt lobes of the gular region. Labrum bearing on its dorsal surface a pair of broad protuberances (fig. 63, *b*) each surmounted externally with a brush of fine hairs and internally with a rounded tubercle bearing 3 peculiarly formed bristles. Antennæ single jointed, cylindrical, about one-fourth as wide as long, situated above the mandibles; basal tubercle truncate, about one-half length of antennæ. Mandibles (fig. 63, *f*, *g*) stout, the crown concave and provided with 2 large external teeth and a smaller dorsal internal one. Maxillæ (fig. 63, *d*) quadrate, each being provided with 2 anterior and 1 lateral tuft of hairs and a short truncate cylindrical palpus. Body integument attached to head capsule at a line passing around head directly behind mandibles. Thoracic and abdominal segments, except anal segment, without external appendages or vestiture of any kind. Circumstigmal tubercles armed on their inner borders with a row of very short spines supported by a row of fine hairs.

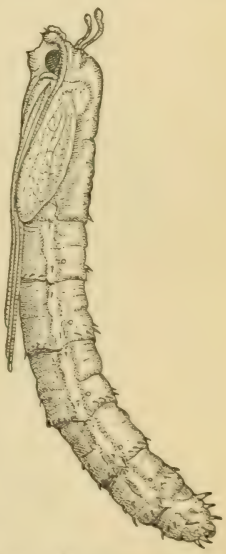

FIG. 64.—The smoky crane-fly: Pupa, lateral aspect. Enlarged. (Original.)

THE PUPA.

Pupa (fig. 64) cylindrical, slightly sinuate in profile, 19 mm. in length and 2 mm. in diameter. Cases containing wings, antennæ, and legs free and lying appressed to venter. General color yellowish brown, the head, wings, antennæ, legs, and thoracic respiratory tubes dark brown. A light yellow stripe bordered by a fuscous line on either side, situated directly ventral to the spiracles, extends from tip of wings to base of anal segment. The fuscous line dorsal to this stripe is continuous with a wide fuscous band along the anterior margin of each segment dorsally, and also with a narrow line defining each annulus. The band is very conspicuous on the fifth segment but rather faint on the others.

Head well defined; eyes prominent. On ventral surface directly between eyes is a prominent tubercle surmounted by a spine. Anterior to this spine and between the antennal fossæ are 2 more spines.

Pronotum bearing a pair of strongly clubbed and distinctly annulated respiratory tubes which are directed anteriorly with the clubs inclined slightly ventrad. Wings extending from a short distance behind eyes to base of first abdominal segment. Third pair of legs extending to base of third segment of abdomen.

Abdomen composed of 6 segments, although, owing to annular constrictions on the first 5 segments, appearing to have 11. Each segment, except anal, provided ventrally with a transverse row of 8 short, marginal spines, and 2 larger and more widely separated spines near anterior margin; segments provided dorsally with a similar transverse row of 10 short marginal spines arranged in groups; the two groups nearest median line consisting of 2 spines each and the groups nearest stigmata with 3 spines each. Dorsal surface of segments directly anterior to this transverse row of spines and posterior to the annulus finely

hairy. Tergum of anal segment bearing 3 pairs of transversely placed, acutely conoidal tubercles; one pair, the tubercles of which are placed near together, situated near middle: a second pair, widely separated and posterior to the first, and a third pair directed caudad, not so widely separated as the second, located at posterior marginal angles. Directly ventrad to the third pair of tergal tubercles is a subquadrate lobe bearing at its outer angles a pair of stout tubercles. A median emargination on the posterior border is continuous with a median groove to the tergum. On each side of this median groove and directly below the terminal pair of tergal tubercles are 2 conchate cavities, probably stigmal in function.

LIFE HISTORY.

On March 20, 1908, a number of tipulid larvæ (*Tipula infuscata*) were sent to this office by Mr. E. W. Lawrence, of Jackson, Tenn., with the statement that they were completely destroying Japan clover (*Lespedeza striata*) in the tenth district of Madison County, and this paper deals exclusively with our subsequent investigations of this particular species.

Early in October the adults (figs. 60, 61) of this species are abroad in great numbers among tall, rank grass, clover, and weeds, from which they rise awkwardly, as one approaches, flying but a few yards before alighting. They continue abundant in the field during the greater part of October, belated individuals being found about Washington, D. C., as late as October 30.

From material received from Jackson, Tenn., the first adults appeared on October 5, 1 male and 3 females emerging. These females mated almost immediately after emerging, but died without ovipositing. On October 20 a female that emerged on October 13, and that had remained mated for over sixteen hours, began ovipositing on the slate bottom of the rearing cage. She would deposit three or four eggs in a given place and then move on excitedly an inch or more and repeat the process. On being placed in a pot of earth she seemed more at home, elevating her body on the long legs, holding the abdomen perpendicular to the surface of the ground, then slowly moving forward, bobbing up and down, and apparently feeling the ground with the tip of her ovipositor until she found a crevice or hole, when she would let her abdomen into the cavity, deposit a few eggs, and move on to repeat the process at the next crevice encountered. That the Tipulidæ normally flip the eggs about while flying seems very doubtful, but under adverse circumstances, such as being caught in spiders' webs, as one often sees them, they undoubtedly use this means, though probably not intentionally, of dispersing their eggs. A specimen of this species etherized for examination threw out 176 eggs by sudden sidewise movements of the upper and lower genital plates, much as one would snap the fingers. One egg was thrown to a distance of 10 inches.

The average number of eggs laid by one female of this species, as determined by confining recently fertilized females in separate rear-

ing cages and by dissecting the abdomens of females that had just emerged, was approximately 300. This number had also been found to be about the egg-laying capacity of *Tipula bicornis*, as from three specimens Prof. F. M. Webster (1892) obtained 297, 282, and 289 eggs, respectively; and also of *Tipula tephrocephala*, from the abdomen of a female of which 255 eggs were obtained. A specimen of *Tipula angustipennis* which the writer collected at Pullman, Wash., however, contained 602 eggs, and Mr. E. O. G. Kelly found that a confined specimen of an undetermined Tipula from Kansas laid 417 eggs. The eggs laid in our rearing cages failed to hatch, but from the notes made by Mr. E. O. G. Kelly on the egg stage of an undetermined species in Kansas they probably hatch in from one to three weeks.

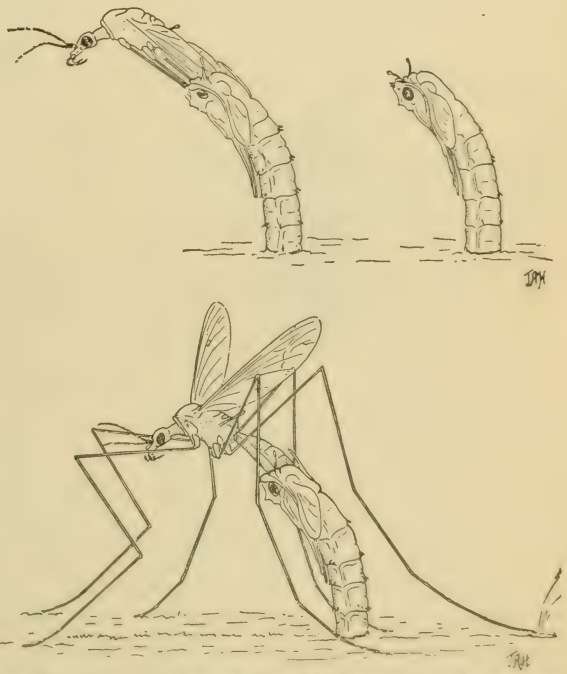

FIG. 65.—The smoky crane-fly: Adult, emerging from pupal case. Enlarged. (Original.)

The larvæ (fig. 63, *a*), which often occur in enormous numbers, as many as 200 having been found in an area covering a little over 1 square foot, feed upon the roots of various plants, seeming to prefer the Leguminosæ, and, contrary to most published accounts of the habits of these larvæ, they not only suck the juices of the roots but devour the plant tissue itself, as is evidenced by the stomach contents of several larvæ examined in this office. Moreover, the well-developed biting mandibles would indicate a tissue feeding habit. They feed during the early fall and hibernate as half-grown larvæ, resuming activities in the spring. In feeding, these larvæ move about in the ground quite freely, as is evidenced by the small molehill-like ridges which they leave, in going from plant to plant just under the surface of the ground. They become full grown about the middle of July, form perpendicular cells about 3 or 4 inches underground, and remain inactive until about the middle of September, when they pupate. The pupal stage lasts from a week to ten days. The pupa (fig. 64)

then, by means of the abdominal spines, works its way to the surface, from which it protrudes about two-thirds of its entire length (fig. 65). By swaying backward and forward the rapidly drying pupal skin is soon split across the back of the head and down the dorsum of the thorax. The swaying movement now serves to work the adult out until the legs are freed, when with their aid it rapidly extricates itself. The males usually appear first and are swarming in the fields when the females emerge, so that the latter are mated when their wings are hardly dry. In Pullman, Wash., the writer observed a small cloud of Tipulidæ (*Dicranomyia venusta* Bergr.) on April 27, 1909, hovering under the eaves of the government field insectary. Other similar observations have been made on other species and C. N. Ainslie (1907) noted that with *Trichocera bimacula* Walk. this was a mating process.

FIG. 66.—*Admontia pergandei*, a parasite of *Tipula infuscata*. Enlarged. (Original.)

NATURAL ENEMIES.

PARASITES.

Among insect parasites but one is known to attack this species or, as far as the writer knows, any other tipulid in this country. It is a small tachinid fly, *Admontia pergandei* (fig. 66), described by Mr. D. W. Coquillett in 1895. These parasites were first noticed in the rearing cages in which the Tipula larvæ were confined, on October 7, when 4 specimens emerged. Within the next week 15 more specimens were taken from this cage. This genus is recorded as parasitic on Tipulidæ in Europe, but heretofore has not been recorded as such in this country. A female of this tachinid was dissected and found to contain 103 elongate-elliptical white eggs measuring 0.564 mm. in length and 0.146 mm. in diameter.

OTHER INSECT FOES.

Prof. F. M. Webster records the carabid beetles *Pterostichus lucublandus* Say and *P. femoralis* Kirby as probably predaceous on these tipulids. He also records (1888) the larvæ of *Harpalus* sp. and *Platynus* sp. as preying on the larvæ and pupæ of Tipulidæ at Anderson, Ind., and the ant *Aphænogaster fulva* Roger as found in the act of dragging a living adult tipulid over the ground.

The larvæ of *Trombidium* sp. and *Rhyncholophus* sp. are often found attached to the base of the wings and abdomen of tipulids.

BIRDS.

Among the birds which are known to feed upon the Tipulidæ, either as eggs, larvæ, or adults, probably the most important are the wood thrush (*Hylocichla mustelina*), the Alice thrush (*Hylocichla aliciæ*), the catbird (*Dumetella carolinensis*), the robin (*Planesticus migratorius*), and the crow (*Corvus brachyrhynchos*). Of the total stomach contents of 22 specimens of the wood thrush, examined at the Illinois State Laboratory of Natural History, 12 per cent was made up of tipulid fragments, while 11 specimens of the Alice thrush contained 8 per cent of tipulid fragments.

The following species also, according to the records of the Bureau of Biological Survey, are known to feed to a greater or less extent on Tipulidæ or their eggs:

Franklin gull (*Larus franklini*).
Woodcock (*Philohela minor*).
Wilson snipe (*Gallinago delicata*).
Killdeer (*Oxyechus vociferus*).
Ruffed grouse (*Bonasa umbellus*).
Mississippi kite (*Ictinia mississippiensis*).
Yellow-billed cuckoo (*Coccyzus americanus*).
Black-billed cuckoo (*Coccyzus erythrophthalmus*).
Kamchatkan cuckoo (*Cuculus canorus telephonus*).
Downy woodpecker (*Dryobates pubescens*).
Yellow-bellied sapsucker (*Sphyrapicus varius*).
Red-headed woodpecker (*Melanerpes erythrocephalus*).
Flicker (*Colaptes auratus*).
Texan nighthawk (*Chordeiles acutipennis texensis*).
Nighthawk (*Chordeiles virginianus*).
Kingbird (*Tyrannus tyrannus*).
Arkansas kingbird (*Tyrannus verticalis*).
Crested flycatcher (*Myiarchus crinitus*).
Black phœbe (*Sayornis nigricans*).
Phœbe (*Sayornis phœbe*).
Say phœbe (*Sayornis sayus*).
Wood pewee (*Myiochanes virens*).
Western wood pewee (*Myiochanes richardsoni*).
Western flycatcher (*Empidonax difficilis*).
Yellow-bellied flycatcher (*Empidonax flaviventris*).
Least flycatcher (*Empidonax minimus*).
Traill flycatcher (*Empidonax trailli*).
Acadian flycatcher (*Empidonax virescens*).
Wright flycatcher (*Empidonax wrighti*).
Blue jay (*Cyanocitta cristata*).
Steller jay (*Cyanocitta stelleri*).
Bobolink (*Dolichonyx oryzivorus*).
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*).
Red-winged blackbird (*Agelaius phœniceus*).
Bicolored red-winged blackbird (*Agelaius gubernator*).
Meadowlark (*Sturnella magna*).
Bullock oriole (*Icterus bullocki*).
Baltimore oriole (*Icterus galbula*).
Brewer blackbird (*Euphagus cyanocephalus*).
Purple grackle (*Quiscalus quiscula*).
Aleutian rosy finch (*Leucosticte griseonucha*).
Snowflake (*Passerina nivalis*).
Aleutian savanna sparrow (*Passerculus sandwichensis*).
Junco (*Junco hyemalis*).
White-throated sparrow (*Zonotrichia albicollis*).
White-crowned sparrow (*Zonotrichia leucophrys*).
Swamp sparrow (*Melospiza georgiana*).

Song sparrow (*Melospiza melodia*).
Fox sparrow (*Passerella iliaca*).
Lazuli finch (*Cyanospiza amœna*).
Western tanager (*Piranga ludoviciana*).
Purple martin (*Progne subis*).
Cliff swallow (*Petrochelidon lunifrons*).
Barn swallow (*Hirundo erythrogaster*).
Tree swallow (*Iridoprocne bicolor*).
Bank swallow (*Riparia riparia*).
Rough-winged swallow (*Stelgidopteryx serripennis*).
Cedarbird (*Bombycilla cedrorum*).
White-eyed vireo (*Vireo griseus*).
Least vireo (*Vireo pusillus*).
Black and white warbler (*Mniotilta varia*).
Yellow warbler (*Dendroica æstiva*).
Audubon warbler (*Dendroica auduboni*).
Macgillivray warbler (*Oporornis tolmei*).
Maryland yellowthroat (*Geothlypis trichas*).
Yellow-breasted chat (*Icteria virens*).
Wilson warbler (*Wilsonia pusilla*).
Redstart (*Setophaga ruticilla*).
Brown thrasher (*Toxostoma rufum*).
California thrasher (*Toxostoma redivivum*).
Cactus wren (*Heleodytes brunneicapillus couesi*).
Rock wren (*Salpinctes obsoletus*).
Dotted canon wren (*Catherpes mexicanus punctulatus*).
Bewick wren (*Thryomanes bewickii*).
Long-billed marsh wren (*Telmatodytes palustris*).
Plain titmouse (*Bæolophus inornatus*).
Black-capped chickadee (*Penthestes atricapillus*).
Carolina chickadee (*Penthestes carolinensis*).
Mountain chickadee (*Penthestes gambeli*).
Wren tit (*Chamæa fasciata*).
Bush tit (*Psaltriparus minimus*).
Ruby-crowned kinglet (*Regulus calendula*).
Wilson thrush (*Hylocichla fuscescens*).
Russet-backed thrush (*Hylocichla ustulata*).
Swainson thrush (*Hylocichla ustulata swainsoni*).
Alaska hermit thrush (*Hylocichla guttata*).

FUNGOUS ENEMIES.

The prevalence of a fungous disease (*Empusa* sp.) among the larvæ and pupæ of tipulids (*Pachyrhina ferruginea* Fab.) at Farmersburg, Ind., is recorded by Professor Webster. When attacked by this disease the larvæ and pupæ come completely out of the ground, turn black, and die. On October 27 a female *Tipula infuscata* in one of the rearing cages was found dead and covered with a decided fungous growth. The fungus was determined by Mrs. F. W. Patterson, of the Bureau of Plant Industry, as *Sporotrichum densum*, and may prove to be parasitic.

REMEDIAL AND PREVENTIVE MEASURES.

Several remedial measures have been recommended against tipulids in general by different writers, from time to time, among which might be mentioned sprinkling the ground with salt, herding sheep and hogs in infested fields, and rolling the ground with a heavy roller. Probably the best method of treating an infested field is to plow the sod under in the early fall and either to run the field into corn,

potatoes, and such crops, or to leave it fallow the ensuing summer. Pastures and hay fields in localities where this species is known to be abundant should be grazed off by the middle of September and kept so until late in November, as the adult flies usually congregate in rank growths of grass, clover, weeds, etc., and there lay their eggs.

LARVÆ OF CRANE-FLIES AS ACCIDENTAL INHABITANTS OF MAN.

While we have no knowledge that any of our American Tipulidæ directly affect man, in a contribution to The British Medical Journal of February 12, 1910, No. 2563, page 371, Dr. W. Soltau Fenwick, in a contribution under the head of "The existence of living creatures in the stomach as a cause of chronic dyspepsia," cites two instances, as follows: "In two apparently authentic cases (Lasalle, Sentex) larvæ belonging to the family of Tipulidæ or crane-flies were detected in the vomit and fæces. Of this, the best-known species is the *Tipula longicornis*, or daddy-long-legs, which deposits its eggs on the ground, whence they possibly gain access to the human stomach by means of unwashed vegetables and fruit. The grubs, which are tough-skinned and hard-headed, are well known to gardeners by the name of leather jackets."

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PAPERS ON CEREAL AND FORAGE INSECTS.

THE COWPEA CURCULIO.

(*Chalcodermus æneus* Boh.)

By Geo. G. Ainslie,
Entomological Assistant.

INTRODUCTION.

Among the insects investigated during the summers of 1908 and 1909 in South Carolina, and especially in the vicinity of Clemson College in that State, the cowpea curculio, hitherto known as the cowpea-pod weevil, was found to be very abundant and destructive. This beetle (fig. 67, *a*) is bronze-black in color, about a quarter of an inch long, with the thorax and elytra deeply and abundantly pitted. Damage is caused to cowpeas by punctures made in the pods and "peas" by the adults for the purposes of feeding and oviposition and by the feeding of the larvæ within the maturing "peas." The damage, though seemingly widespread, is not very evident, as it affects the value of the crop only where the "peas" are grown for seed. More serious injury is done by this species in early spring to young cotton, which it is forced to use for food. Individual cotton plants or the entire stand in a field may be injured or completely destroyed.

Very little has been written on this insect, although the entomologists of Texas and other southern States frequently receive specimens and requests for information concerning its habits. As it has a superficial resemblance to the Mexican cotton boll weevil and is frequently found in cotton fields, it is one of the species often taken by the cotton growers to be that dreaded pest and as such has many times been sent to southern entomologists for verification.

In spite of its wide distribution and common occurrence, its life history had probably not been determined until within the last two years. Notes on its habits and distribution have been obtained from several sources, among others from the records of Messrs. Hunter and Chittenden and by correspondence from Prof. Wilmon Newell, now entomologist of the Texas Agricultural Experiment Station. The data regarding the habits of the larvæ and all the definite life-history records were obtained by the writer during the summer and fall of 1908 and 1909 at Clemson College, S. C.

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The writer wishes to acknowledge his indebtedness to Prof. F. M. Webster for suggestions during the progress of the work and for assistance in preparing the material for publication.

PUBLISHED RECORDS.

The species was first described by Boheman, in Schoenherr's Genera et Species Curculionidum, volume 4, page 388, Mexico being given as the habitat. The distribution of this insect, as given in the Biologia Centrali-Americana, volume 4, part 4, 1902–1906, includes Mexico, at Cosamaloapan in Veracruz, at Jalapa, and at Teapa; British Honduras, at Rio Hondo and Rio Sarstoon; and Guatamala, at Chiacam and San Gerónimo in Vera Paz.

In his paper entitled "Contribution to a Knowledge of the Curculionidæ of the United States," published in 1873, Horn gives the distribution as Georgia and Florida, but mentions no food plant.

In 1894, in Insect Life, Dr. L. O. Howard briefly reported the determination of two parasites reared from *Chalcodermus æneus* by Prof. H. A. Morgan at Baton Rouge, La.

During the progress of some extensive jarring experiments carried on in Georgia in 1901 by Messrs. Scott and Fiske this beetle occurred commonly among the insects taken from peach and plum, and is so recorded in Bulletin 31 of this Bureau.

In the Yearbook of the United States Department of Agriculture for 1903, Dr. F. H. Chittenden mentions the species as having been reported injuring cotton in the Southern States, stating further that the insect did not breed on cotton but on cowpeas.

In February, 1904, Doctor Chittenden published in Bulletin 44, this Bureau, the most extensive article that had appeared on this pest up to that time.

In September, 1904, Prof. E. Dwight Sanderson lists and briefly describes it as one of the insects mistaken for the boll weevil.

In 1905, in Bulletin 57 of this Bureau, Professor Sanderson notices the insect as one injurious to cotton and, quoting Professor Newell at length, gives a description of the injury done to cotton and somewhat of the habits of the beetles.

Prof. Franklin Sherman, jr., in a bulletin from the North Carolina Department of Agriculture, June, 1908, again lists the species as injurious to cotton and briefly summarizes the knowledge from the sources already mentioned.

In a study of the breeding habits of the Rhynchophora of North America, published from the University of Nebraska, Mr. W. Dwight Pierce gives a very brief summary of the literature dealing with the habits of the species and further states that it has once been reared from a cotton square, a fact nowhere else recorded. A brief mention of this same insect is made by the same author in Bulletin 73 of this

Bureau, in 1908, and again in the Journal of Economic Entomology the parasites so far reared from the species are listed.

From this brief summary of the literature it appears that this insect, which breeds almost altogether in cowpeas, has been considered very largely as a cotton insect.

DISTRIBUTION.

The distribution of this weevil probably coincides with that of the cowpea, but since the injury to cotton is more noticeable it has seldom been reported from beyond the cotton belt. It has frequently been recorded from eastern Texas, Louisiana, Alabama, Florida, Georgia, South Carolina, and North Carolina, and less frequently from Oklahoma, Maryland, and Missouri. In his notes on the species Boheman mentions Mexico as its home, and Horn had specimens from Georgia and Florida. It is, without much doubt, of southern origin and has probably spread northward, following the introduction and use of the cowpea.

FOOD PLANTS.

In its breeding this curculio seems to be confined almost entirely to the cowpea and closely related legumes. According to Mr. W. D. Pierce, one adult was reared from a cotton square at Mexia, Tex., July 31, 1905, by Dr. W. E. Hinds. This is the only instance in which any plant outside the legume family has served as a host, and the occurrence can probably be considered as accidental.

In June, 1908, adults were plentiful on wax beans at Monetta, S. C., and although well-formed pods were present the beetles did not seem to be breeding. Mr. Pierce reports the breeding of the beetles on cowpeas, beans, and string beans, but no records have been published regarding the two latter plants.

In the spring cotton is often damaged seriously while it is small by the adult beetles, but as this trouble occurs only on land on which cowpeas were grown the preceding year it is apparent that cotton is a food plant from necessity rather than from choice. Later in the season beetles in confinement have starved to death rather than feed on nearby young cotton. In an insectary experiment at Clemson College, S. C., in the fall of 1908 a large number of the beetles were confined in a cage in which were growing cowpea plants, bearing pods, and cotton plants, both young and medium sized. The cowpea pods were first attacked and within a couple of days were reduced to dry remnants because of the great number of punctures. Then the stem and petioles of the plant were punctured but not seriously. The young and old cotton plants showed no sign whatever of having been touched and, although no other food was given, the beetles went into hibernation, leaving the cotton untouched.

In a letter Prof. Wilmon Newell says of the species in Louisiana:

The adult weevils are of quite common occurrence in cotton fields late in the season; that is, during July, August, and September. They evidently feed to some extent on cotton plants at that time, so that I believe cotton can be normally considered as one of their food plants but not properly a host plant.

It is quite possible that when driven to it by hunger in early spring other plants, wild or cultivated, are eaten to some extent. The fact that this species was reported as "conspicuously numerous" on plum and peach trees in the spring of 1901 in Georgia would seem to indicate some such habit.

The original food plant is not known but was undoubtedly some wild legume growing farther south than the present distribution of the insect in the United States.

DESCRIPTIONS.

This beetle has never been technically described in English, the only description of the adult being that of Boheman, in Latin. The other stages have never previously been described.

The egg (fig. 68, *c*).—The egg is subelliptic, obtusely rounded on the ends, 0.9 mm. long, 0.6 mm. broad, white, translucent when first laid but gradually becoming more opaque. The shell is smooth and shining. Just before hatching the brown mandibles of the larva can be seen through the shell, which is very thin and delicate.

The larva (fig. 67, *b*, *c*).—Length, 7 mm.; width, 2.5 mm.; thickness (dorsoventral), 2 mm. Body footless, largest about one-third back from the head, from there tapering to a rather acute cauda. Composed of 12 segments, 8 of which bear spiracles showing as yellowish or brown dots. Each segment also bears 8 minute brownish bristles, two on each side of the dorsal line and two on each lateral margin. Color pale yellow, dorsal plates on first segment brownish yellow. Head about one-third the greatest width of the body, vertical, dark amber-yellow with a white Y-shaped suture in front, the stem of the Y bordered with white.

The pupa (fig. 67, *d*).—Length, 5 mm.; width, 3 mm. Of much the same shape as the adult except that the abdomen is longer and more acute.

When newly formed it is pure white and is ornamented with numerous regularly arranged, dark-colored bristles. As it matures it darkens, the eyes, proboscis, and extremities of the elytra first showing the pigment.

The adult (fig. 67, *a*) (translated from Latin of original description).—Subovate, dark bronze; proboscis slender, moderately curved; thorax deeply and remotely punctate, obscurely carinate; elytra deeply pitted with scattered conspicuous punctures, the interstices minutely punctulate; femora acutely serrate.

With the size and all the characters of *Chalcodermus metallini* but never larger; thorax deeply punctate, obscurely carinate, between the elytra minutely punctulate, farther back distinctly punctate. Head globose, obscurely bronze, evidently, but less deeply punctate; eyes ovate, slightly projecting, black; proboscis never longer than the thorax, somewhat slender, round, moderately curved, obscurely bronze, from the base above the middle carinate, rough-striate, minutely punctulate below. Antennæ inserted at the middle of the proboscis behind, somewhat slender, black, sparingly pilose, club oblong-ovate, acuminate, cinereous-pubescent. Thorax narrower at the base and anteriorly, globose, the apex above never roundly produced, at the base bisinuate, convex above, obscurely bronze, dorsum sparingly and, toward the sides, closely and deeply punctate, the longitudinal lines somewhat elevated and prominent. Scutellum small, circular, obscurely bronze. Elytra wider at the

base of the thorax anteriorly and three times as long as the latter, the shoulder obtuse, somewhat rounded; lateral margins straight, toward the apex very slightly narrowed, the apex itself taken together obtusely rounded, convex above, obscurely bronze, somewhat polished, with rows of deep, round, excavated pits, the even surface between minutely punctulate; femora moderately clavate, below and behind the middle armed with acute robust teeth; tibiæ compressed, somewhat bowed, with teeth obsolete; tarsi elongate, with yellow pads below.

FEEDING HABITS.

Feeding punctures made by both males and females in cowpea pods can not be outwardly distinguished from the egg punctures. They are made in the same places on the pod and by the same methods, some of the beetles even going so far as to enlarge the cavity at the bottom of the excavation, probably because they prefer the tissue of the peas themselves to that of the pods as food. If either a feeding puncture or an egg puncture reaches and penetrates a pea it causes an abnormal development of the kernel even though no larva develops. The pea becomes gnarled, one-sided, and light in

FIG. 67.—The cowpea curculio (*Chalcodermus æneus*): *a*, Adult; *b*, larva; *c*, head of same; *d*, pupa. *a*, *b*, *d*, Enlarged; *c*, more enlarged. (From Chittenden.)

weight and will be lost in the threshing or winnowing. The damage caused by the feeding operations of the adult beetles on cowpeas is not serious.

As the writer has not had opportunity to observe the work of the beetles on cotton the following description of such injury is quoted from Prof. Wilmon Newell as it occurred in Georgia in 1904:

Injury by this species was personally investigated at Herod, near Dawson, Ga., May 27, 1904. Beetles were found upon about 15 acres of cotton, from 4 to 10 beetles on each plant. The plants were about 4 inches high. The beetles feed for the most part in the afternoon or early morning and upon cloudy days, although a few may be found on the plants at noon on bright days. The beetle punctures the tender stem, often just below a leaf, and this puncture reaches to the very center of the stem or occasionally to the epidermis of the opposite side. Punctures occur upon leaf stems and the upper tender part of the main stem near the ground. The punctures upon leaf stems are so close as to practically sever the stem; the leaf soon withers and dies and drops. In some cases the beetles seem to stay over the puncture after it is made and suck up the sap which accumulates. In several cases we found a beetle upon the shady side

of the stem, remaining over or close to several punctures, indicating that a single individual may make several punctures and take the sap that accumulates in all of them. Punctures in a case of this kind are not over one-sixteenth or one-eighth of an inch apart, and from two to four are found in each group. We are inclined to think that the punctures are made purposely for securing the sap and not for devouring the tissue. Eight punctures were counted on a plant not over 2 inches high, and in this field were found an average of from 5 to as many as 16 beetles on and about each plant. In this 15-acre field fully 25 per cent of the cotton stalks had been killed by the attacks of this beetle, and in some small areas as much as half had been killed. * * * They occurred also on neighboring farms, but in no other case in such injurious numbers. In all cases the owners of infested fields reported that the first appearance of these insects in the cotton was in those portions of the fields that had been in cowpeas the year previous. About three weeks later—May 27—the injury became less, owing to the more rapid growth of the plants, and perhaps also to the greater dissemination of the beetles.

HABITS AND LIFE-HISTORY RECORDS.

The life habits of this species and the length of the life stages were worked out by Doctor Chittenden in 1903 and published by him in 1904 in Bulletin 44 of this Bureau. Because of the fact that his records were obtained under unnatural and unfavorable conditions they must be revised somewhat in the light of more recent work.

THE EGG.

In preparing the nidus for her egg the female sits quietly on the pod of the cowpea and with her mandibles excavates a cavity through the pod into the pea beneath. The opening is about as large as the diameter of the proboscis of the beetle and about as deep as it is long. After it has reached the proper depth the beetle begins to revolve slowly around the opening, feeding at the same time and evidently preparing a cavity at the bottom of the excavation for the reception of the egg. The curculio is very deliberate in all her movements and the preparation of the nidus takes from three-quarters of an hour to an hour and a half. After its completion she withdraws her proboscis, turns, crowds the tip of her abdomen close down into the hole, and oviposits. A brief examination with her proboscis to determine that all is well completes the operation.

The egg lies usually within the pea itself, more rarely in the parenchymatous tissue between the peas or between the pod and the pea. It may be sunk so slightly into the pea as to part from it when the pod is removed or buried so deeply that it can not be seen from the exterior when the pod is opened. This depends on the thickness of the pod and the size of the individual beetle which placed the egg. The egg is pushed in with the end first but lies usually with its long axis more or less parallel with that of the pea. The punctures are made as a rule about one-third of the way around the pod from the

dorsal suture, evidently at the place where the pod is thinnest. So regularly are they made that a badly infested pod will show a distinct row of the punctures running along each side of this suture. A few punctures are also made on the ventral side of the pod in about the same relation to the ventral suture. Thus the egg lies on the upper surface not far from the hilum, or well down on the side (fig. 68, *a*, *b*, *d*).

Very shortly after the beetle leaves the egg the puncture fills with sap and in from twenty-four to forty-eight hours a tough callous has formed over the opening. In a ripe pod the wound shows as a dark, slightly elevated, and somewhat roughened transverse ridge.

For purposes of oviposition the pods are not attacked until the peas within them have reached nearly or quite full size. No pods are oviposited in after they begin to become dry and leathery.

Cloudy cool days or the cooler parts of bright days are chosen by the beetles for oviposition and feeding. During a slow rain they are very abundant and active. During the hotter parts of the day they remain motionless in the axils of the plant or buried in the loose earth surrounding the stem.

FIG. 68.—The cowpea curculio: *a*, Cowpea pod, showing work of adults; *b*, *d*, "pea," showing work of larvæ; *c*, eggs. *a*, Reduced; *b*, *c*, *d*, about natural size. (Original.)

At Orlando, Fla., in 1907, Mr. H. M. Russell, of this Bureau, made some records of the number of eggs deposited by a single female. I quote from the record of these experiments.

On July 6 the following experiments were made to determine the number of eggs a female would lay:

A. A male and female were put together in a box of cowpeas.
B. A male and female were put together in a box of cowpeas.
July 8 A laid 26 eggs; B laid 36 eggs.
10 A laid 26 eggs; B laid 17 eggs.
12 A laid 42 eggs; B laid 20 eggs.
15 A laid 15 eggs; B laid 13 eggs.
17 A laid 6 eggs; B laid 7 eggs.
18 the A beetles escaped; B laid 0 eggs.
22 B laid 22 eggs.
27 B laid 18 eggs.
August 3 the B beetles died.
A laid 115 eggs in 10 days.
B laid 130 eggs in 19 days.

Many attempts were made to determine the exact incubation period of the egg. In most cases when a pea bearing an egg is removed from the pod, decay and fungous growths cause its destruction before it can hatch. Some, however, were obtained which remained in good condition long enough to hatch and in other cases freshly laid eggs were removed and placed on damp blotting paper. After repeated trials 3 eggs, whose age was accurately known, hatched. One hatched in four days and the other two in six days each. Enough other records were obtained under less accurate conditions to show that the normal incubation period is five or six days, with a shorter time when the temperature averages higher.

THE LARVA.

The brown mandibles of the larva show through the delicate membranous covering of the egg before hatching. The shell is broken by the abrasion of the mandibles, and by its contortions the larva works the almost invisible shell backward off its body, whence it is finally discarded as a minute white pellet. The larva lies extended in the egg and after hatching appears sluggish, beginning to feed on the tissue in its immediate vicinity and making no effort to change its position. It gradually turns toward the inside of the pea, growing almost as fast as the pea is consumed. In nearly every case it eventually gets into the central cavity, which is present between the two halves of a growing pea. A semiliquid, pale yellow frass appears and finally closes the comparatively small opening through which the entrance to the pea was made. Unless it is too small to afford sufficient food or too dry to be edible, a larva seldom leaves the pea in which the egg was originally placed, until ready to pupate. In one or two instances, where the pods in breeding cages were allowed to become too dry, half-grown larvæ were found wandering along in the pod looking for suitable food. When placed in holes cut in fresh peas they went at once to feeding and completed their growth.

During its growing period a larva consumes about one-third the volume of a normal pea (fig. 68, *d*). Very rarely two larvæ reach maturity in one pea, but never more, although several eggs have been found in close proximity.

It is difficult to determine how many times a larva molts. The exuvium is so ephemeral that no part of it can be found except the cast of the head. Two of these brown head castings are often found in one burrow, but the writer has been unable to find more. The increase in size is gradual, without apparent change as to the characters of the larva.

Mr. W. D. Pierce states that "the species of the genus Chalcodermus pupate in the feeding cells instead of entering the ground."

His information regarding *C. æneus* was probably derived from the results of Doctor Chittenden's cage experiments, carried on in Washington, D. C. In no case, out of the several hundred beetles reared by the writer, did one pupate before leaving the pea and the pod in which the larva developed.

When full grown, the larva cuts a hole to the outside of the pea and then through the pod and drops to the ground. The opening in the pod is frequently at some distance from the injured pea. It is quite regular, circular in outline, about 2 mm. in diameter, and the disk which is cut out often remains hinged at one side. After dropping to the ground the larva immediately begins to burrow into the earth. In well-settled, damp sand the larva can disappear in about one minute. In the fall of 1908 several big jars of cowpea pods were kept under observation. The larvæ emerging from the pods contained therein were each day transferred to small jars containing damp sand. Several hundred larvæ were thus obtained and practically every one of them disappeared into the sand as soon as the opportunity was offered. The larva penetrates the ground to a depth of from 1 to 4 inches, depending on the compactness of the latter. Two jars were prepared with equal depths (about 2 inches) of damp sand, that in the first being settled as compactly as possible and that in the other put in loosely. Eighteen larvæ were put into the first and of this number only 3, or 17 per cent, reached the bottom, while, of 33 put into the loose sand, 10, or 30 per cent, reached the bottom. The larger and more active grubs burrow deeper and more rapidly. After reaching the necessary depth, the larva by the motion of its body proceeds to form an oval cavity somewhat larger than itself. It spins no cocoon whatever.

The exact time of hatching of several larvæ was determined, and these were transferred to fresh peas. The young larvæ do not seem to be able at first to penetrate the smooth coat of the pea, but when an opening is made for them they accept it at once. The length of the larval period spent in the pea was accurately determined for 12 larvæ. In most cases the larva had to be transferred to fresh food one or more times because of the decay of the mutilated pea. These 12 larvæ fed as follows; Four fed for 7 days; 2 fed for 8 days; 1 fed for 9 days; 4 fed for 10 days; and 1 fed for 12 days. This gave an average feeding period of 8¾ days for the lot. The larval period in the pea can safely be said to vary from 7 to 14 days, depending on the temperature and the food supply.

After entering the ground the larvæ do not pupate at once, but remain quiescent for several days in the earthen cells. In 11 jars in which the length of the period was recorded all the visible larvæ had pupated in 5 days, in 8 jars it required 6 days, and in 2 jars 7 days, giving 6 days as the average and from 2 to 8 as the probable extremes.

THE PUPA.

The pupal cell is usually found with its long axis inclined or vertical, and the pupa lies with the head up. The pupa is easily disturbed, and manifests its excitement by very rapid rotation of its abdomen.

In order to determine the conditions necessary for pupation, 18 larvæ were divided into three equal lots, and on September 30, 1909, 6 were placed on a damp brick and covered with a glass dish, allowing them to remain in the light; 6 were placed on a damp brick and covered with a tin box, excluding the light, and the remaining 6 were shut in the dark in a dry paper box. Two of the first lot had pupated October 13, on the 16th 2 more, and on November 3, 2 adult beetles were found, all the others being dead. In the second lot 3 had pupated on October 13 and on the 16th 2 more. Three adults had emerged November 3. None of the larvæ in the dry box pupated, showing that while earth and darkness are not essential to pupation moisture is.

The pupal period was determined in a great number of cases. During the fall of 1908 especially, large numbers of the larvæ were collected and placed in small jars containing damp sand, so that the date of emergence of the adult beetles could be easily observed. Below is shown the time elapsing between the entrance of the larvæ into the sand and the emergence of the adults:

5 beetles emerged in 14 days.
36 beetles emerged in 15 days.
72 beetles emerged in 16 days.
169 beetles emerged in 17 days.
72 beetles emerged in 18 days.
49 beetles emerged in 19 days.
26 beetles emerged in 20 days.
5 beetles emerged in 21 days.
1 beetle emerged in 22 days.
1 beetle emerged in 23 days.
21 beetles emerged in 24 days.
1 beetle emerged in 25 days.

This gives for the 458 beetles an average of 17.4 days spent underground. Subtracting from this the 6 days spent as a larva underground, the actual pupal period is determined as being about $11\frac{1}{2}$ days, with extremes of 8 and 19.

THE ADULT.

The beetles push slowly up through the soil and are quite active when newly emerged. They seem never to fly, but in the field are very ready to "play possum," and drop to the ground at the least disturbance. In falling they do not draw up their legs, but leave them extended, and for this reason are much easier to find on the

ground than are many members of the family. They frequently are coated with mud, and when so protected become almost invisible when on the ground. After dropping they often lie twenty minutes before making the slightest motion.

It requires, then, something over a month for the generation to develop, allowing 6 days to the egg, 9 days to the larva in the pod, and 6 in the ground, and 11 days to the pupa.

SEASONAL HISTORY.

The cowpea curculio passes the winter in the adult stage, going into hibernation when its food supply is destroyed in the fall with the first severe frosts. In the vicinity of Clemson College, S. C., this occurs in the latter part of October or early November.

No out-of-door records as to the exact place of hibernation have been made, but an experiment carried on in the greenhouse will indicate the probabilities. In the fall of 1908 some 200 of the beetles were confined by a wire-screen cage to an area of ground about a yard square, on which were growing cotton and cowpea plants. The beetles were left in this cage, and by the latter part of November had largely disappeared, although the house was kept at summer heat.

At several different times during the winter examinations were made, and the beetles were found buried in the earth at a depth of from 1 to 3 inches. As late as March 15, 1909, beetles were found in the earth, and on this date one was observed sluggishly climbing a blade of wheat growing near by. The beetles winter, then, hidden under rubbish or lumps of earth or buried from 1 to 3 inches deep in the earth itself.

The beetles emerge from hibernation as soon as the weather fairly warms up. The earliest date at which they have been reported in various localities is as follows: Arnaudville, La., April 16, 1908; Coffee County, Ala., May 13, 1904; Stillwater, Okla., May 20, 1909; Benson, N. C., May 24, 1907; Messers, S. C., May 28, 1909; southeastern Missouri, June 15, 1907; Monetta, S. C., June 17, 1908; Orlando, Fla., July 6, 1907. These are not, of course, the dates at which the beetles emerged from hibernation, but indicate that they were active at least by these dates.

Coming out in the spring hungry, they are willing to attack young cotton and probably other fresh plant growth as it appears. It is a very general custom to follow cowpeas with cotton in the rotation, and in every case where damage to young cotton has been reported it has been on a field planted to cowpeas the preceding year.

The beetles, feeding on cotton, cowpeas, and other young plants, exist until the cowpea pods become of sufficient size to permit oviposition. This date varies greatly with the season. In 1908 half-grown larvæ were found on August 1, showing that eggs had been

laid by the middle of the preceding month, while in 1909 no pods large enough to contain eggs were found in the vicinity of Clemson College until September 7, when eggs and a few very small larvæ were found. Oviposition continues until the supply of green pods fails. About a month after the first eggs are laid adults of the new generation begin to appear. Repeated attempts were made to induce these young beetles to oviposit, but entirely without success. In confinement they fed readily on green pods, but would not oviposit when beetles of the over-wintering generation were producing eggs freely under the same conditions. It seems to be true that only one generation is produced annually, but in localities where two distinct crops of cowpeas can be matured there may prove to be two generations of the beetles. As the season draws toward its close, individuals of the older generation die off very rapidly. Probably few of them enter and none emerge from hibernation the second winter. Of 11 beetles of the 1909 generation confined with food in a cage, 3 had died when the experiment was discontinued late in the fall of 1909, while of 21 beetles of the 1908 generation confined under the same conditions, only 3 remained alive at the same time.

PARASITES.

On September 18, 1908, there emerged from the sand in a breeding jar a fly subsequently determined by Mr. D. W. Coquillett, of this Bureau, as *Myiophasia ænea* Wied. (fig. 69). Between that date and October 2, 1908, when the last one emerged, 60 of these flies appeared. There were 683 beetle larvæ put into these jars; 517, or 76 per cent of the lot, emerged as adult beetles; 60, or 8.8 per cent, appeared as parasites, leaving 15.5 per cent unaccounted for, but probably killed by fungus or dryness. The flies belonging to this species emerged during a period of from 16 to 28 days after the coleopterous larvæ entered the ground, the average for the lot being slightly less than 21 days.

An examination of the puparium shows that the dipterous larva does not leave the body of its host, but uses it for a pupal case. The body swells slightly, becomes brownish and hard, and apparently no attempt is made to pupate, the coleopterous larva dying soon after entering the ground. The fly emerges through a transverse slit in the posterior end of the puparium and seems to have no trouble in forcing its way through any ordinary amount of soil to the surface.

Numbers of the adult flies were confined in a jar containing a supply of the beetles and green cowpea pods, in which eggs of the latter had been laid. The actions of the flies were suspicious. They wandered slowly over the pods, seemed interested in the punctures, and in several instances were seen to touch the tip of the abdomen quickly to a puncture. A careful dissection of the pods revealed nothing, however, that could be taken for eggs or larvæ of the fly. In this connec-

tion I quote from a letter from Mr. C. H. T. Townsend dealing with this species:

I have just dissected a fresh specimen of *Ennyomma globosa* [*Myiophasia ænea*], collected here to-day. It is the species you bred from *C. æneus*. The specimens you gave me showed only ova in the egg tubes—undeveloped because no copulation had taken place. This fresh specimen contained many very slender, elongate—unusually elongate—eggs containing developing maggots. They are tapering at both ends. If the fly deposits eggs, the eggs must hatch in a very short time. It is possible that the eggs hatch in the uterus, and that the fly deposits living maggots. What light this throws on the habits I can hardly say. Is it possible that the fly deposits eggs in the weevil puncture and that the weevil eggs hatch first? Or can it be possible that the fly deposits a maggot that waits till the weevil egg hatches? I can not believe that the weevil egg can be entered by the maggot and still develop with the maggot inside. * * * These *Ennyomma* eggs are so minute that they can hardly be seen with the naked eye. * * * After thinking the matter over further, it seems likely to me that the flies deposit living maggots in weevil punctures of a certain age, and that these minute, spindlelike maggots bore into the old weevil puncture and follow the hatched weevil larva. The female fly has no piercing ovipositor. Everything points to the deposition of living maggots.

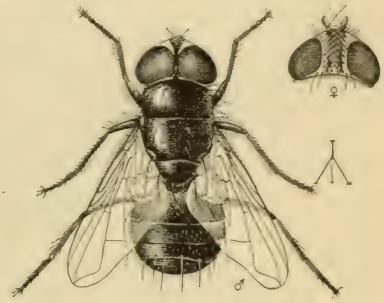

FIG. 69.—*Myiophasia ænea*, a parasite of the cowpea curculio: Adult male and head of female. Enlarged. (Original.)

Two other species of parasites, both hymenopterous, one a Eupelmus and the other a eurytomid, and both probably undescribed, as I am informed by Prof. F. M. Webster, have been reared from the larvæ of this beetle at Clemson College, S. C. Individuals of both of these species appeared on the cloth covering of jars containing cowpea pods, so nothing more is known of their life history than that they pupate in and emerge directly from the pod. During the fall of 1909 one such hymenopterous pupa was found in the cavity made in a pea by a curculio larva, beside the remains of the larva itself, but it was not reared, and so to which one of the species mentioned above this individual belonged is not known. A female of one of these species was observed in the act of ovipositing in a cowpea pod on August 27, 1908. She thrust her ovipositor through the tissue of the pea, and as the other species has also a piercing ovipositor it is probable that both place their eggs directly in the body of the half-grown larva within the pea.

In 1894 Dr. L. O. Howard recorded *Ennyomma clistoides* [*Myiophasia ænea*] and *Sigalphus* sp. as having been reared by Prof. H. A. Morgan from *Chalcodermus æneus* at Baton Rouge, La. These same rearings are again reported by Mr. W. D. Pierce in the Journal of Economic Entomology.

When the sand in which they were pupating was kept too damp, larvæ and pupæ were several times killed in the breeding jars by an undetermined fungus.

REMEDIES.

In so far as cotton is concerned, the sovereign remedy would seem to be to refrain from planting it on land previously occupied by cowpeas infested with this pest. If this is not practicable the cotton may be planted thick, and by delaying the "chopping" or thinning as long as possible a uniform stand may still be secured. Planting cowpeas with the cotton would probably cause the beetles to confine their attentions to the former plant. Hand-picking of the beetles has been tried by planters in North Carolina without apparent diminution of their numbers. One grower gathered over 5,000 of the beetles from 3 acres of cotton in nine days.

The larvæ, as a rule, do not emerge from the pod until the pods are well ripened. If therefore the crop is being grown for seed the pods may be gathered frequently as they ripen. If stored in a tight, dry bin the larvæ as they emerge will be unable to complete their development. Spraying with arsenicals, if thoroughly done, would probably be efficient, as Doctor Chittenden suggests, but such an expense would be entirely impracticable in the great majority of cases. Parasites are so abundant that there is no prospect of serious damage, except for short periods over limited areas.

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